DIE-CASTING

MACHINES · DIES · ALLOYS

Edward Jacobi
12 Oct 1953

DIE-CASTING

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The Die-Casting Process and Its Application in Modern Manufacture, Die-Casting Machines, Design of Different Types of Dies, Composition and Properties of Die-Casting Alloys, and the Die-Casting of Zinc, Aluminum, Brass, and Other Non-Ferrous Alloys

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Die-Casting Process and Its Applications

The production of castings by applying pressure to force molten metal into steel dies or molds is one of the notable developments in modern manufacturing practice. Die-casting, as this process is termed, provides a means of producing unlimited quantities of castings of such uniformity and accuracy that machining costs are either reduced greatly or eliminated entirely. The process is applicable to castings extending over a considerable range of sizes, in an endless variety of shapes, and of a wide selection of metals. Intricately cored parts can be readily cast.

Die-castings are inherently smooth on both external and internal surfaces because they are formed against finished metallic surfaces of the dies and their cores. Another important advantage is the absence of the sand inclusions which commonly occur in sand castings with the result that tools used for machining die-castings have a long life between grinds when machining is required. Die-castings can be produced to sharp outlines and with thin sections that would be entirely impractical in sand casting. Strength is another feature of die-castings that is derived from their close-grained structure.

The application of die-casting involves: (1) the use of a die-casting machine arranged to hold and operate the dies and to fill them repeatedly with the molten metal used in forming the casting; (2) equipping the machine with dies adapted to whatever form of casting is to be made; (3) use of a die-casting alloy having physical properties suitable to the application for which the casting is intended.

Some firms specializing in the production of die-castings employ die-casting machines of their own design. There are also commercial makes of machines ranging from very simple hand-operated types designed for simple work and possibly small production to highly developed automatic machines capable of rapid production and the making of intricate castings in a great variety of forms. The small hand-operated and semi-automatic machines on the market are used in general where mass production is not required. Some of these relatively simple types, however, are capable of large production in the casting of small parts. For the larger castings, and particularly where production is large and interior cores must be used, a machine designed to eliminate hand control is, in general, more economical and may be essential to satisfactory work.

The Die-Casting Process Defined.—The term "die-casting" generally refers to a casting that has been made in a metallic mold or die, into which molten metal has been forced by the application of either mechanical, pneumatic, or hydraulic pressure. Die-castings do not include so-called "hot-pressed" or "die-pressed" forgings. The definition also excludes castings that are poured by gravity into metallic molds, the latter generally being known as "permanent-mold" castings. Die-castings may be defined as castings produced by forcing molten metal into metallic dies by a force greater than atmospheric pressure. This definition differentiates them from the class of castings made by the permanent mold process.

The process of die-casting consists essentially in melting the die-casting alloy in a suitable container and forcing it, under pressure, into metallic molds or dies, allowing it to cool in them, and then opening the dies and removing the casting, thereby producing smooth finished castings which require little or no machining and are ready for buffing or plating without any grinding or other abrasive process. The method is best adapted to the production, in quantity, of small and medium size parts where accuracy and uniformity are essential.

Castings made with a Polak type of machine have been called "pressure castings"; in fact the term *pressgus* (press casting) was applied originally to castings made by this process which has been classed as intermediate between extrusion and true die-casting. (With a Polak machine the metal is cast in a plastic or semi-liquid condition, as explained later in connection with brass die-casting.)

Developments in Die-Casting.—In many mechanisms and devices, die-castings now play an important part. Frequently the use of the die-casting process has made possible the development of designs that would have been too costly to produce by ordinary machining methods, the die-casting being complete when it comes from the mold except, perhaps, for a simple cleaning operation. Gear teeth, projecting studs, and cam surfaces can be produced without machining, and of late it has been found possible not only to produce very intricate die-castings, but parts of large dimensions as well. The use of die-castings effects a great saving in time and labor cost, in machine equipment, and in the expense for building jigs, fixtures and tools of various kinds.

Alloys have been developed for the die-casting process which possess strength, ductility, and resistance to shock to such an extent that they approach mild steel in their characteristics; and alloys are now being cast that formerly were considered impossible to handle by this process.

Applications of Die-Castings.—The die-casting industry is constantly assuming greater importance in the industrial field. With the improvements that have been made in die-casting alloys and die-casting machines and methods, it is now possible to use die-castings for many purposes in machine construction for which they could not have been used only a few years ago.

The automobile industry, as is well known, has long made extensive use of the products of the die-casting industry; in fact, the automotive industry is the "star" customer for die-castings, both from the tonnage standpoint and from the standpoint of prestige. Every automobile is a traveling salesman for die-casting manufacturers. From fancy radiator grille and brightly shining horns to flashing tail lights, it advertises the fact that the die-casting process makes possible the economical production of articles in the fine appearance class. Under the hood are other die-castings that serve as examples of maximum utility and mechanical exactness.

The machine builder—even the builder of machine tools—has found it advantageous to employ die-castings for many purposes for which formerly metals that required extensive machining operations were used. Many small machines are assembled almost completely from die-castings. In the construction of the intricate mechanism of a certain sales register, for example, thirty-nine zinc-alloy die-castings are used. This greatly reduced the number of parts that would otherwise have been required, and materially cut the machining and assembly costs.

This machine is not by any means an isolated case of the use of die-castings for the principal parts of small machines. Meat slicers, home tin-can sealers, kitchen mixers, and juice extractors, postage meters and many similar business machines are constructed in this manner.

The electrical field is continually including more die-castings in new designs. The rotor for a squirrel-cage induction motor is one of the most interesting applications made in this field in the last few years. The assembly of one electric hoist, built in capacities of 1/2, 1, and 2 tons, is now 75 per cent zinc die-cast. Die-castings are found on portable electric tools and many other appliances.

This trend toward complete assemblies by die-cast parts is probably due to a fuller comprehension on the part of machine designers of the possibilities of die-casting design. The possibility of combining several parts, formerly consisting of stampings, castings, and screw machine products, into one die-casting, conserves space, reduces cost, and results in a more rigid construction.

The importance of the die-casting industry has been further augmented by the adding of brass die-castings to the wide application of zinc and aluminum die-castings. Through the brass die-casting method, intricate brass parts that have heretofore presented a difficult or costly production problem can now be produced economically. Parts that formerly had to be made in separate units and soldered or joined by other means can now be die-cast in a single operation.

Use of Die-Castings in Lathe Construction.—A lathe which has forty-three die-cast parts is an example of the increasing use of the die-casting process in many different lines of manufacture. This lathe is designed to sell at a very low price. In order to produce a good lathe at low cost, it was found necessary to embark upon new construction methods and to adopt new materials. The zinc die-casting metal known as "Zamak-2" is used. Laboratory tests have shown that this metal has a tensile strength of from 40,000 to 45,000 pounds per square inch.

Gears, gear housings, gear carriers, pulleys, handwheels, and graduated dials are among the parts that are die-cast. The die-castings have an added advantage in that there is assurance that all duplicate parts will be uniform in size, since they are made in the same master die.

Miscellaneous Examples of Die-Casting.—The die-casting process is now applied in so many different lines of manufacture and to such a wide variety of work that it is impossible to present in this book enough examples to indicate the present-day use of the die-casting process. In fact, several volumes of this size might be filled with illustrations of die-cast parts without including more than a fraction of the possible number; however, a few examples of die-cast parts are illustrated on the following pages to give those unfamiliar with die-casting practice some idea of its vast possibilities. These few examples represent castings ranging from small simple designs to intricate and large sizes in order to show a varied cross-section of die-casting practice. These preliminary examples will be followed by a large variety of others that are accompanied by detailed descriptions, photographs and drawings of the dies used in their production. The die might be described as the "business end" of the machine; and since the exact details of its design depend upon the form of the part to be produced, most of the examples of die-casting shown in this book are accompanied by illustrated descriptions of the dies used.

The two illustrations, Fig. 1, show aluminum die-castings that are excellent examples of the possibilities of die-cast metals. The left-hand illustration shows a base and cover

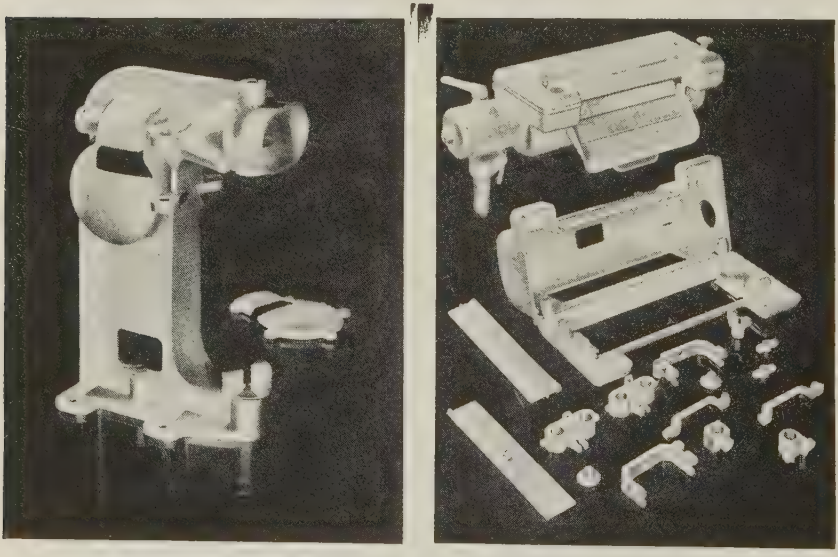


Fig. 1. (Left) Die-cast Aluminum Base and Cover Plate for an Automatic Canning Machine. (Right) Automatic Washing Machine Wringer Made from Aluminum Die-castings—Aluminum Co. of America

plate for an automatic canning machine; that to the right, an automatic washing machine wringer and the parts used in its construction. Light weight, combined with the required strength, is assured by the use of die-castings for these parts.

The automobile grille shown in Fig. 2, designed by the Doehler-Jarvis Corporation in collaboration with the Packard Motor Company, is an example of the possible size of zinc die-castings. This one-piece casting measures 60 inches in width. If a multi-piece assembly had been used, smooth blending of the various contours on this part would have been difficult to achieve, and then only at greater cost.

The aluminum oil base shown in Fig. 3 is an example of an exceptionally large die-casting. The die or model for this part weighed 4 tons and was constructed in four weeks at a cost of $6000. The weight of this die-cast oil base is 17 1/2 pounds; length, 34 inches; width, 10 inches; depth, 5 inches. The wall thickness is 0.1 inch. All holes are cast to the finished size. The tapping of some of the holes is the only machine work on this part.

Additional examples of both typical and unusual die-castings are shown in Figs. 4 to 11, inclusive. Information about the application in each case may be obtained from the caption beneath the illustration.

Toys, novelties, boudoir-lamp bases, salt and pepper shakers, bearings, and a wide variety of other parts are die-cast from lead, tin, pewter, Britannia metal and babbitt. These ornamental objects, toys, etc., are frequently hollow or what is known as "slush" castings. Castings of this type possess the advantages of being light in weight and low in metal cost.

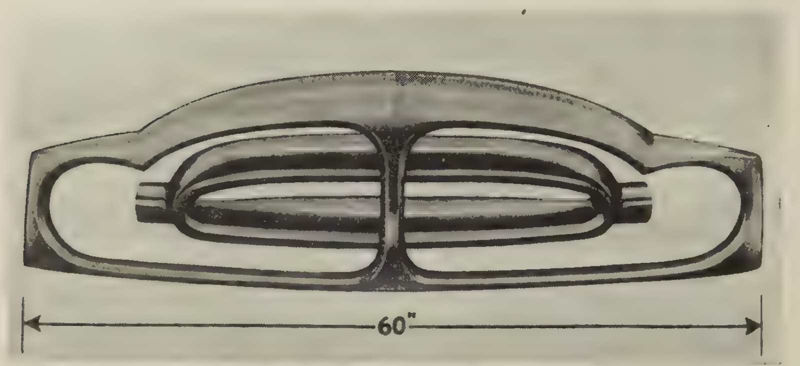


Fig. 2. Automobile Grille Die-cast in One Piece for the Packard Motor Co. is Indicative of the Possible Size of Zinc Die-castings.

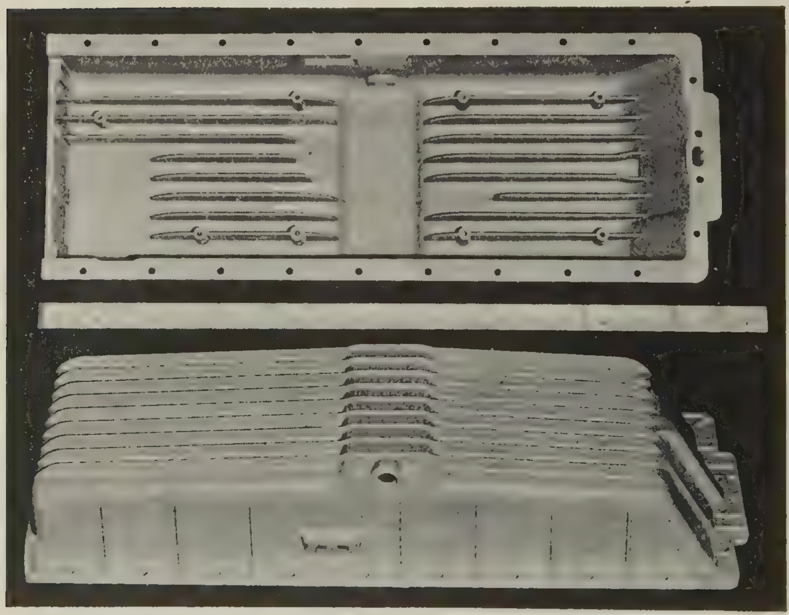


Fig. 3. Aluminum Automobile Oil Base—Example of a Large Die-casting —Precision Castings Co., Inc.

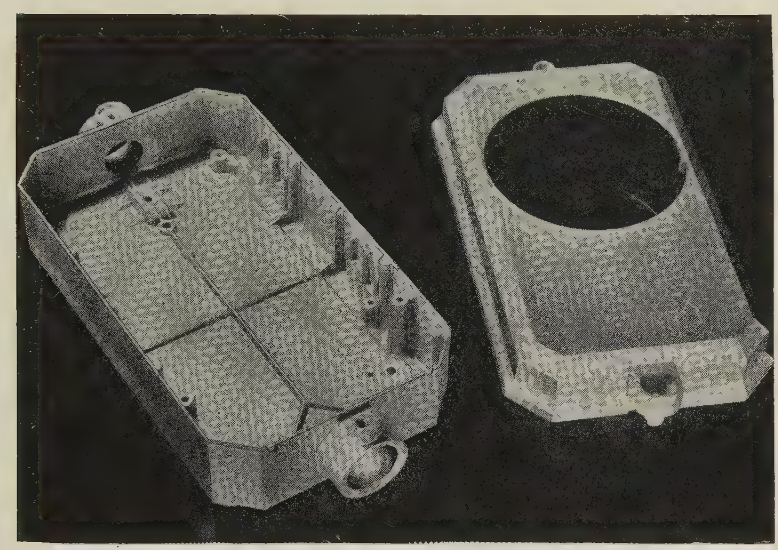


Fig. 4. An Aluminum-alloy Die-cast Meter Case and Cover that Require Practically No Machining or Finishing. The Corrosion-resisting Qualities of the Aluminum Alloy Permit the Use of the Meter Case in Outdoor Applications —Aluminum Co. of America

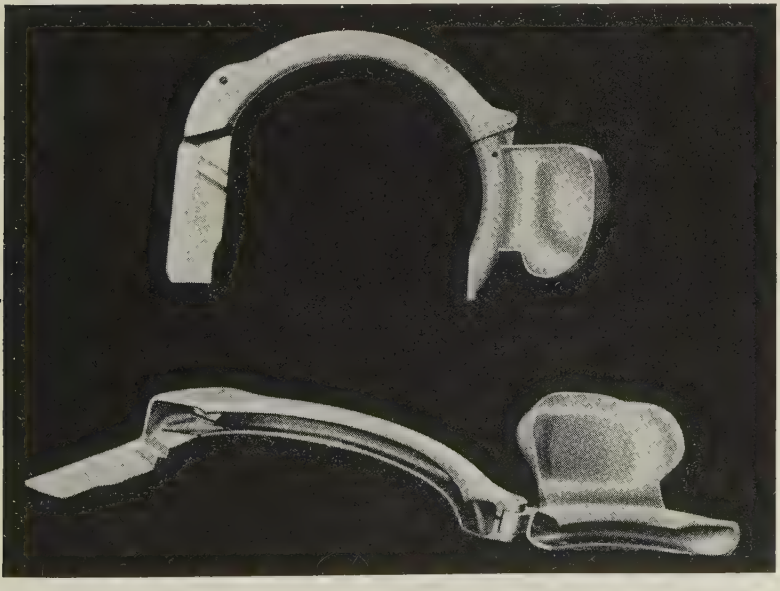


Fig. 5. Die-cast Knife Guards for Food Slicing Machines—the Large Curved Section is 15 Inches Long—Superior Die Casting Co.

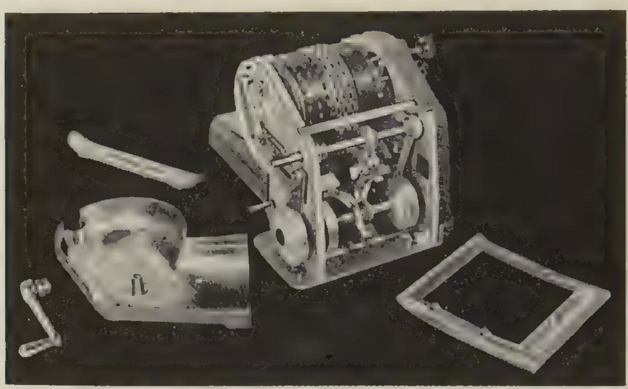


Fig. 6. The Entire Assembly of the "Initialator" is Made up Almost Completely of Zinc Die-castings—New Jersey Zinc Co.

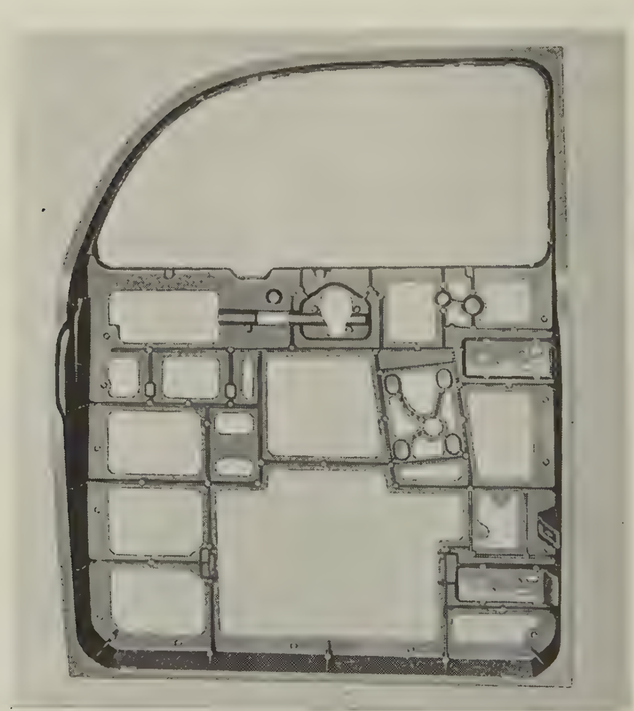


Fig. 7. This Die-cast Aluminum Automobile Door Frame, Produced by the Doehler-Jarvis Corp. Covers an Area of Approximately 1200 Square Inches and Weighs about 12 Pounds when Trimmed. Use of this Door Frame Saves about 35 Pounds in the Weight of a Four-door Car.

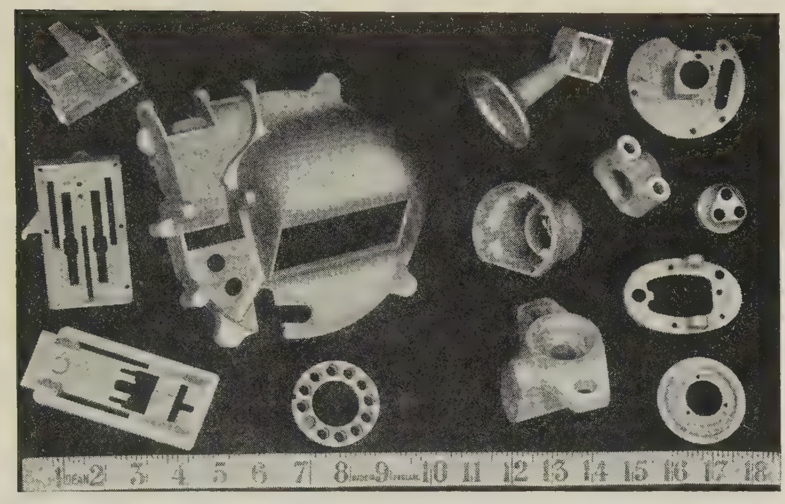


Fig. 8. Brass Die-castings Made by the Doehler Die Casting Co., Combining the Well-known Advantages of Die-castings in General with the Strength of Copper-base Alloys

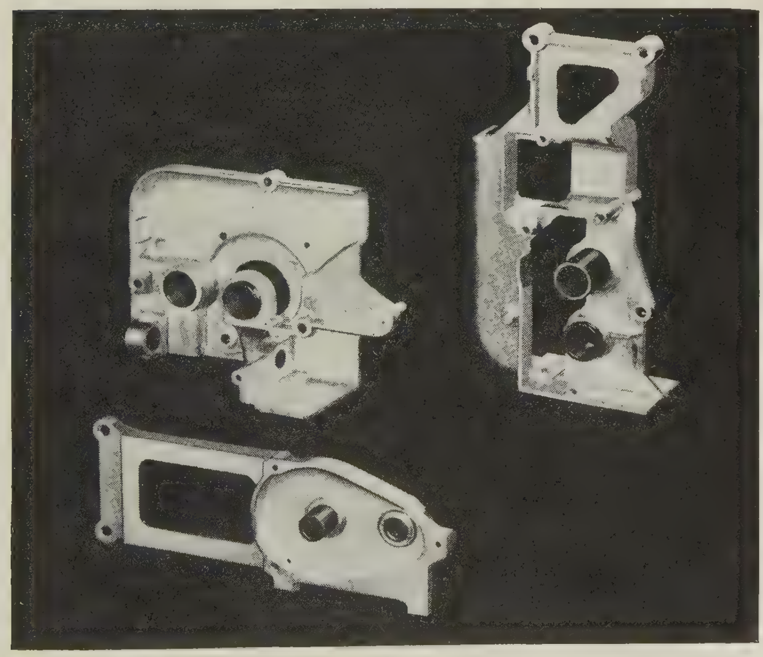


Fig. 9. Threaded-Inserts, Bearings and Studs are Cast in Place in These Zinc Meter-housing Die-castings—Superior Die Casting Co.

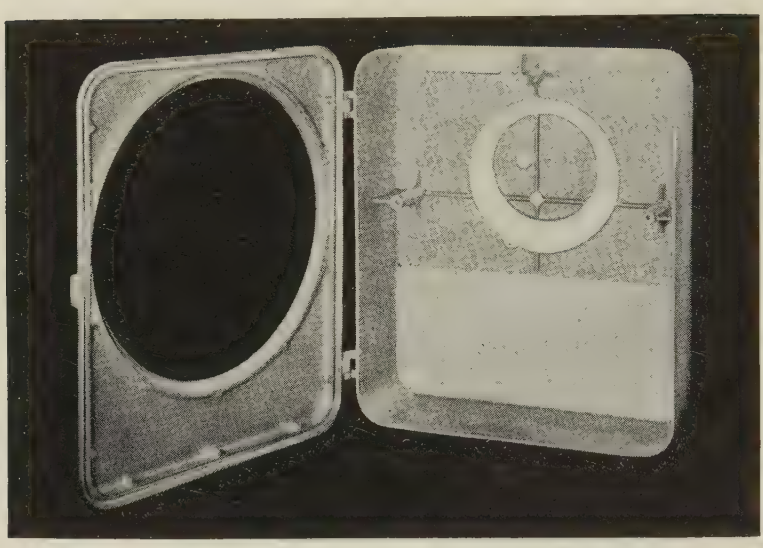


Fig. 10. This Aluminum Meter Case and Cover are 16 Inches High, 4 Inches Deep, and 12½ Inches Wide. The Weight of the Case and Cover is Approximately 8 Pounds

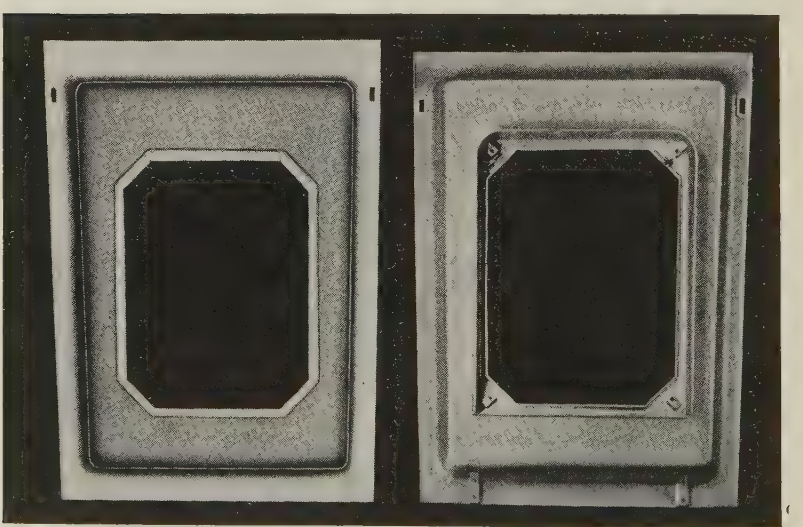


Fig. 11. A Large Zinc-base-alloy Die-casting Approximately 22 Inches High by 15 Inches Wide, Weighing 6 Pounds. This Frame for a Gasoline Pump Dial was Economically Produced, with All the Required Slots and Holes Cast—Superior Die Casting Co.

Die-Casting Machines and Their Development

Die-casting machines have been developed to meet various die-casting problems and also different manufacturing conditions. Die-castings are now made from alloys varying widely as to physical properties and the castings themselves include a wide variety of sizes and forms. When the alloys have a low melting point and the casting is a very simple design, the die-casting operation is also simplified. The use of alloys of relatively high melting points makes it more difficult to produce dies that will withstand the higher temperatures; and when the design of the casting is intricate and there are interior passages to be formed by the use of cores, this not only means a more complicated die but a more highly developed design of machine, especially when quantity production is essential.

In some plants, a simple design of hand-operated machine meets practical requirements, whereas, in other plants, the nature of the die-casting operation or the number of castings required necessitates the use of a more highly developed machine. To meet all of these widely diversified conditions, there have been placed on the market die-casting machines ranging from small manually operated types up to those designed either for mechanical-pneumatic or hydraulic operation with all movements in each cycle performed automatically. Before describing these commercial machines, some information will be given concerning the origin of the die-casting process with illustrations and descriptions of some designs which are interesting from a historical point of view.

Origin of Die-Casting and Early Types of Machines.—The origin of the die-casting process is not definitely known, and establishing the origin would in any case depend somewhat upon the meaning of the term die-casting. The first machines or methods based upon the general principle of die-casting were utilized in manufacturing bullets and type. There were a number of inventions for casting bullets and several patents were taken out in the years preceding and following the American rebellion and the Mexican war. According to the history of type founding, the first machine for casting type was invented by Bruce in 1838. This machine involved the general principle of die-casting.

Die-Casting Machine Patented in 1849.—The first type-casting machine, an illustration of which is available, was patented in 1849 by J. J. Sturgiss. A sectional view of this machine is shown in Fig. 1 (left-hand view); and the operation of the machine is based upon the underlying principle of the die-casting process. In this machine the molten metal flows from the pot *A* which is surrounded with heat, through the opening *B* into the cylinder *C*. Plunger *D* is then forced down by the lever *E*, which is operated by a cam and connecting-rods, and forces the metal out of nipple *F* into the type-mold. Piston valve *G* is then forced forward to squeeze the metal into the mold and also cut off the liquid stream, so it will flow back into the pot.

Machines Patented in 1852 and 1856.— This was followed in 1852 by another patent by W. P. Barr covering other points on a machine which worked in practically the same manner as the Sturgiss machine. In 1856 E. Peluze patented an apparatus on similar lines as shown in Fig. 1 (right-hand view). His improvement over the two former machines was in the piston valve design. Valve *I* was moved back until beveled surface *J* closed opening *K*, through which the molten metal flowed. Plunger *L* was then forced down, and this made the metal flow through

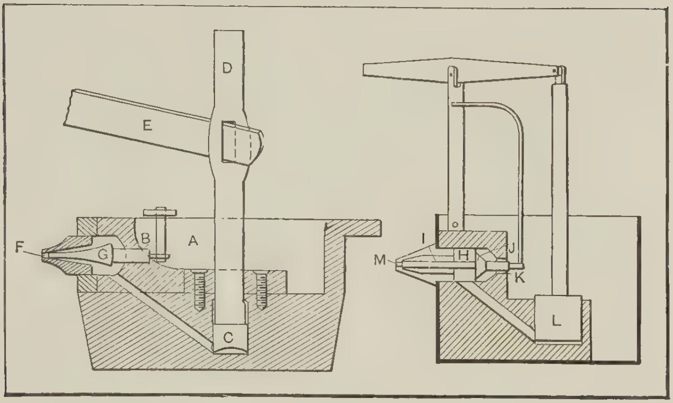


Fig. 1. (Left-hand view) Type-casting Machine Built in 1849. (Right-hand view) Improvement in the Type-casting Machine, Made in 1856

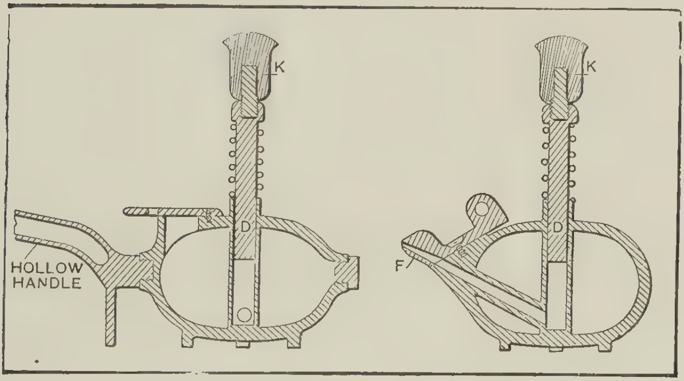


Fig. 2. Small Hand-operated Machine Built in 1872

nipple *M* into the type-mold. After this, piston valve *I* was forced forward.

Hand-Operated Machine Patented in 1872.—In 1872 a small hand machine was patented, as shown in Fig. 2. This was filled with molten metal from a melting pot, and when set on the bench, the palm of the hand was brought down forcibly on the wooden knob *K*. This forced down piston *D* and squeezed the metal out through nipple *F*. Other machines were invented in the following years for making

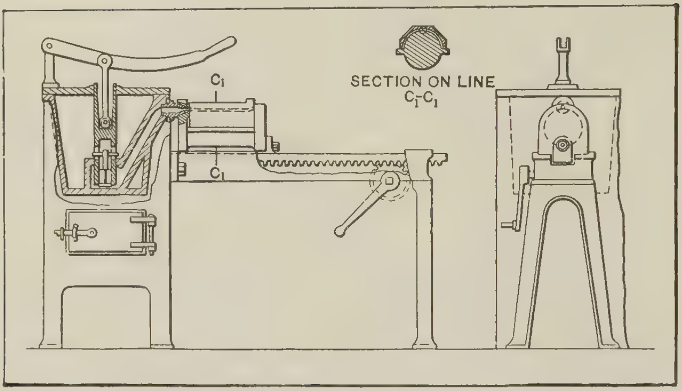


Fig. 3. First Die-casting Machine Built for Miscellaneous Work (1877) Set up for Casting Bearings

medals, sewing machine bobbins and various other small articles. The type-metal apparatus was also improved by such inventions as that shown by the right-hand view, Fig. 4, in which a much better design and arrangement were made of heating chamber, melting pot, cylinder, plunger, etc.

First Machine Designed for Miscellaneous Work.— The first attempt to apply these principles to a more universal manufacture of castings was made by C. and B. H. Dusenbury in the machine shown in Fig. 3, which they patented in 1877. In this, the same principles as used on former machines were adopted for the melting pot, cylinder, plunger, outlet passage and nipple. In addition thereto, arrangements were made by which the die-molds, that contained impressions for journal bearings, were located on the machine, and exchanged for others when desired. Thus a wide range was given to the machine. The mechanism for moving the mold away from the nipple so it could be opened and closed consisted of a gear and rack.

Little was done with this method of casting until after C. W. Weiss was allowed some claims, on March 8, 1892, on practically the same machine that was patented by the

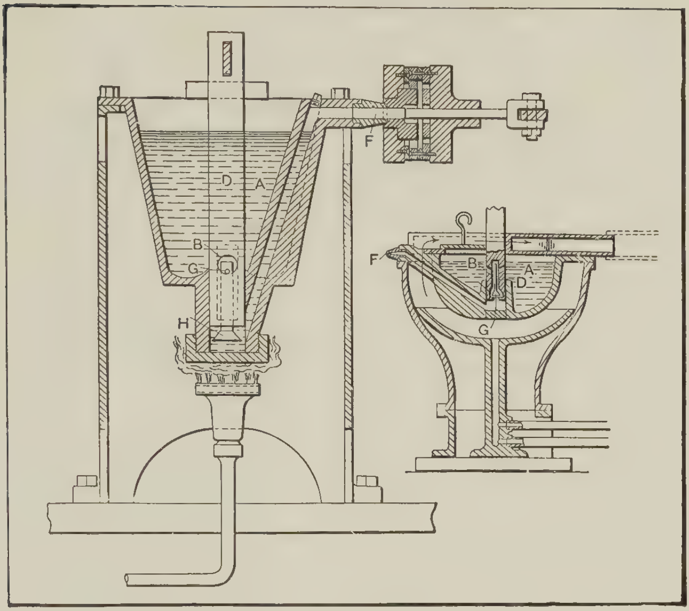


Fig. 4. (Left-hand view) Die-casting Machine Patented in 1892. (Right-hand view) Improvement Made in 1888 on Machine Shown in Fig. 1

Dusenburys in 1877. This is shown in Fig. 4 (left-hand view). From this time on the die-casting business has steadily grown until it is now an important factor in the manufacture of many products.

The Linotype Machine.—The linotype machine which is so generally used at the present time for casting type in one solid line or slug was brought out in 1885 by Otto Mergenthaler. This machine might be classed as a form of die-casting machine, although at the present time the term die-casting embraces numerous products and, according to a general understanding of the term, "die-casting machines" are used to cast parts for many different lines of manufacture and varying greatly in size, shape, and also in regard to physical properties to meet various service conditions.

Pneumatic Die-Casting Machine Patented in 1907.—The compressed air type of die-casting machine patented by

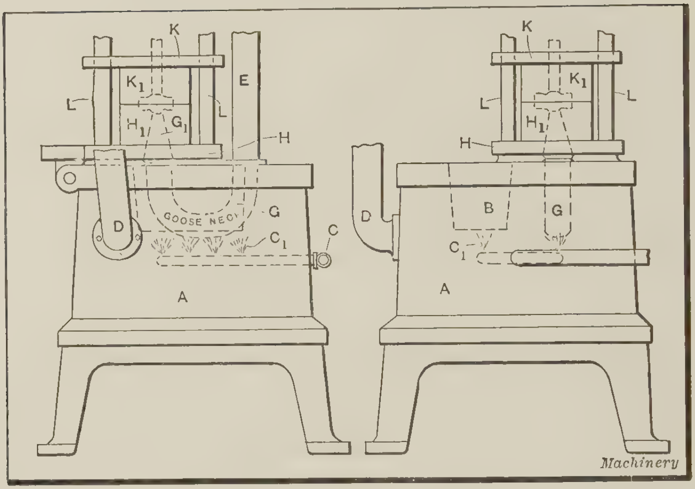


Fig. 5. Drawing Illustrating Principle of Van Wagner Die-casting Machine

E. B. Van Wagner in 1907 is shown in Fig. 5. In the base *A* of the machine is located the melting pot *B*. This melting pot is heated by means of fuel oil passing through the supply pipe *C* to the burners C_1. A vent pipe *D* is provided to take away the gases incident to combustion. The pressure for "shooting" the metal into the die-cavity is supplied by air through the supply pipe *E*. A valve controls this air supply. The pressure is regulated to suit the particular casting or die, the proper amount being determined by experiment. An air exhaust pipe (not shown) is subdivided into two tubes which extend to the die-cavity to exhaust the air before the metal is admitted. There are two methods of overcoming the presence of air in the die-cavity—the exhaust method and the venting method, and it is the former that is here described.

A "gooseneck" *G* serves to contain temporarily the metal which is forced into the mold. An amount of metal slightly in excess of that required for one die-casting is placed in this gooseneck with a hand-ladle, previous to each operation of the machine. One end of the gooseneck is connected to the air pipe, *E*, while the other end terminates in the nozzle G_1. One of the advantages in using this gooseneck is that the entire air pressure is expended upon the metal in the gooseneck, and, by reason of its isolated position, the gooseneck and its contents are kept slightly hotter than the contents of the melting pot.

The lower die is shown at H_1, and the upper die K_1 is mounted upon the upper die-holding plate *K*. Four rods *L* act as guiding members for the upper die-holding plate to slide upon. These rods *L* are mounted in fixed positions at the corners of the lower die-holding plate *H*, passing through die-plate *K* and the die-mechanism plate. The distance between plates *H* and *K* is adjustable, thus providing for the accommodation of thick as well as thin dies.

The metal enters the die-cavity through the nozzle G_1, and after setting, it is necessary to cut the sprue formed by the surplus metal that remains outside the die-cavity. For this purpose, a sprue-cutter, operated by means of a hand-lever (not shown) is employed. In many dies, it is necessary that water be circulated through the die-blocks to keep them cool during the die-casting operation. Water pipes run to each side of the die-blocks in the machine illustrated, thus providing a cooling circulation.

First Commercial Die-Casting Machine.—The Soss die-casting machine was the first machine to be placed on the open market. This machine is shown in Fig. 6. The details will be fully described for the benefit of those interested in the development of die-casting machines. The Soss Manufacturing Co. originally manufactured invisible hinges exclusively. At the beginning of the die-casting era, they commenced to make these hinges from die-castings, and placed orders with a leading die-casting concern. After the die-cast hinges had been on the market for a short time, complaints began to come in, some to the effect that the hinges were breaking and others that the hinges were cor-

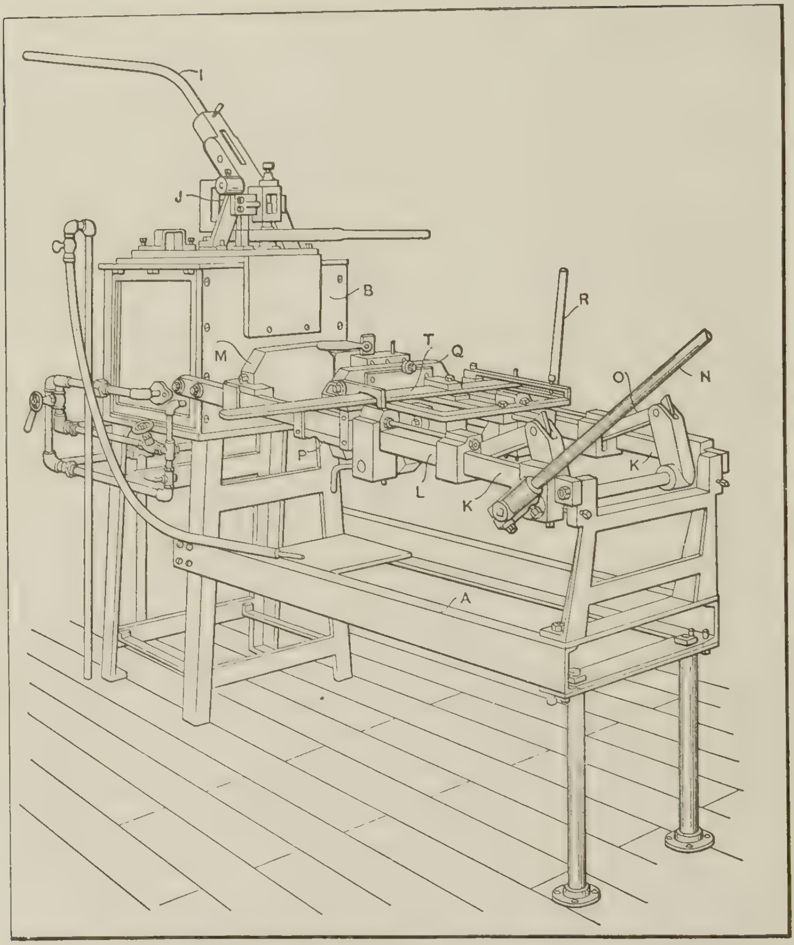
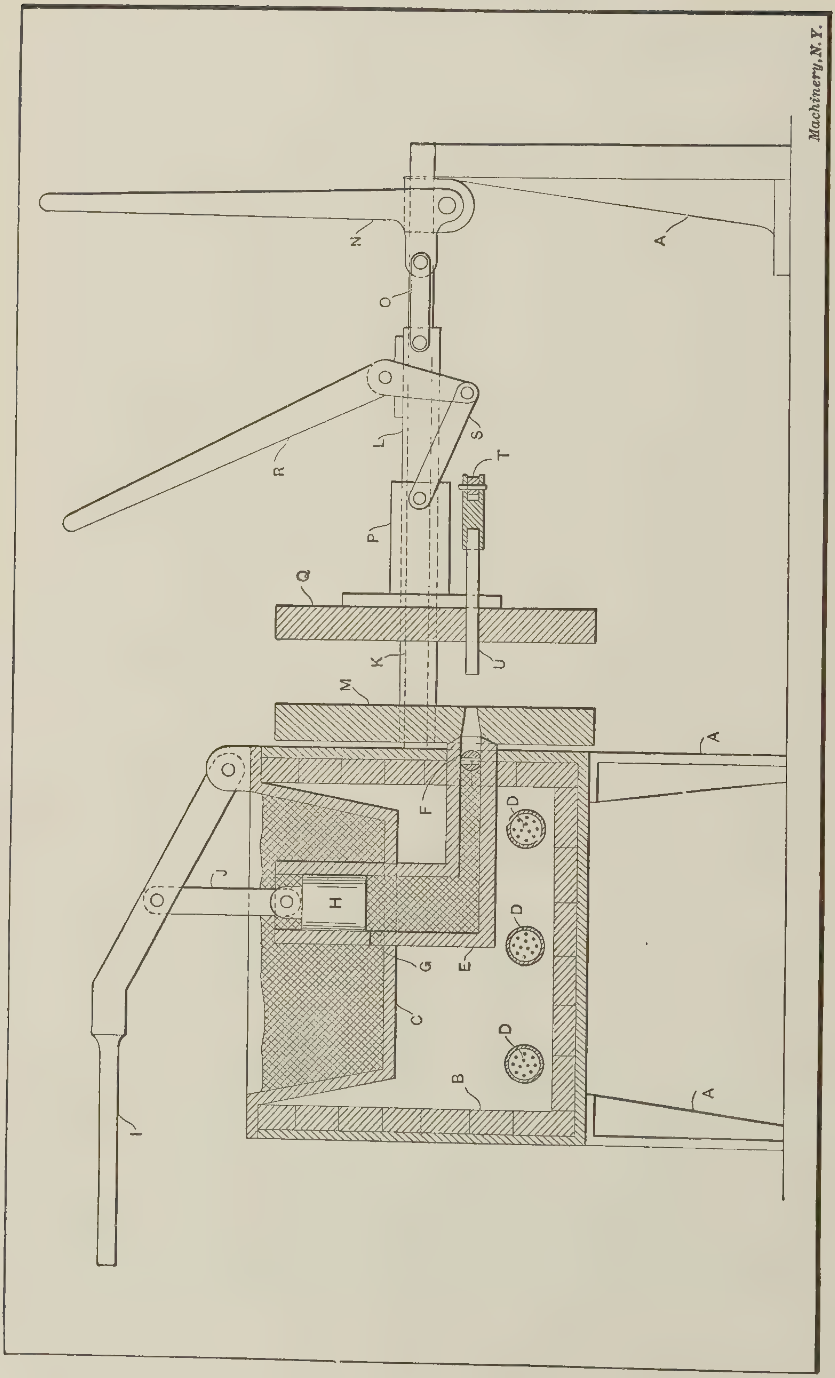


Fig. 6. Working Parts of the Soss Die-casting Machine

roding. Either of these faults was serious enough to blast the reputation of the hinge, but the first trouble, breakage, was the more important. Examination of the broken hinges showed that the castings were porous and full of flaws. As the makers could not produce castings sufficiently strong for the hinges, Mr. Soss started to experiment, and later produced the Soss die-casting machine.

In Figs. 6 and 7, *A* is the base and frame of the machine, *B* is the heating chamber located at one end of the machine, and within this heating chamber is the tank *C*, shown in Fig. 7. This tank contains the metal from which the die-castings are made, and the metal is heated by the burners *D*. These burners are fed by air and gas through piping on the side of and beneath the furnace. To facilitate lighting the burners and inspecting their condition at any time, there is an opening (not shown) through the firebrick lining of the furnace and the outer iron wall, on a level with the top of the burners. There is also another opening through the furnace wall to allow the gases due to the combustion to escape. Through the bottom of the tank, well to the inner side of the furnace, runs the cylinder *E*. Below the bottom of the tank, the cylinder makes a right-angle turn, extending through the furnace wall and terminating just outside of the wall. The orifice of this cylinder is controlled by gate valve *F*. In that part of the cylinder that extends upward into the tank, there is an opening *G* that allows the molten metal to run into the cylinder from the tank. Working in this cylinder is the piston *H*, which forces the metal into the dies. The compression lever *I*, hinged over the inner furnace wall, is kept normally raised by spring pressure, and is connected to the piston by means of the link *J*.

At the opposite end of the machine from the furnace is the mechanism for operating the dies. This mechanism consists of a pair of square rods *K*, upon which are mounted the sleeves *L*. These sleeves have a long bearing surface and are attached to the die-plate *M*. Lever *N* at the end of the operating mechanism controls the movement of these sleeves by means of links *O*. Upon these sleeves is mounted a secondary set of sleeves *P*, attached to the other die-plate *Q*, and their movement is controlled by lever *R*, through links *S*. This second set of sleeves is free to travel with the first set, and in addition has an independent movement of its own on the primary sleeves. It is the function



Machinery, N.Y.

Fig. 7. Section of Soss Die-casting Machine

of lever *R* to bring die-plate *Q* up to die-plate *M* by means of links *S* and sleeves *P;* and it is the function of lever *N* to bring both of the die-plates up to the outlet of the cylinder by means of links *O* and sleeves *L.* This system of sleeve-mounting was one of the distinctive patented features of the Soss machine. The orifice of the cylinder *E* is conical in shape and exactly fits the cup-shaped opening in die-plate *M,* so that when the two are brought together, the joint is metal tight. At the center of this opening, and extending through the die-plate *M,* is a taper hole leading to the dies mounted on the inner faces of the two die-plates, and a continuation of this hole extends through die-plate *Q* in which the sprue-cutter *U* works. Attached to the outer side of this die-plate are two slotted brackets. In the slot of one of these is pivoted the lever *T,* and in the slot in the opposite bracket are bolted two stops that limit the motion of the lever. This lever operates the sprue-cutter *U,* that works through the opening in die-plate *Q.* At the left of Fig. 6 may be seen a rubber hose connected to the air piping. This hose is for cleaning out the dies after each casting operation.

Operation of the Soss Die-Casting Machine.—As soon as the machine has "warmed up," so that the metal is in a thoroughly melted condition, the sprue-cutting lever *T,* Fig. 6, is thrown back, leaving a clear passageway to the die-cavities. Lever *R* is pulled backward, thus bringing die-plate *Q* up to die-plate *M,* which operation closes the two halves of the die. Then lever *N* is thrown forward, thereby bringing the closed die up to the body of the machine, with the nozzle in close contact with the outlet of the cylinder. Next, the gate *F* is opened, and the man at the compression lever *I* gives the lever a quick, hard pull, forcing the metal in the cylinder downward and into the dies. The molten metal "squirts" into the dies. Gate *F* is now closed; lever *N* is pulled back to remove the dies from the cylinder outlet; and the sprue-cutting lever *T* is pushed forward, cutting off the sprue and pushing it out of the nozzle into the kettle placed beneath it. The lever *R* is pushed forward and a finished casting is ejected from the dies.

Small Hand-, Foot-, and Air-Operated Semi-Automatic Machines.— Machines designed especially for the production of small die-castings with inexpensive dies were formerly sold by the Madison-Kipp Corporation, Madison, Wis., in a number of models known as "Kippcasters." These machines are partially hand-operated, foot-operated, and air-operated. They may be oil- or gas-fired. One of the important features is the quickness with which dies can be changed, thus readily adapting the machines to the production of a variety of castings.

The Model 115, illustrated in Fig. 8, is constructed with the furnace assembly located on the right-hand side of the machine and so it is designed for side-gated dies. The gooseneck is indicated by dotted lines. Molten metal is forced into the dies by means of an air-actuated displacement plunger. In the operation of this machine, the dies are closed by the operator turning a spider wheel with his left hand. This die-closing action, through a toggle arrangement, also rocks the furnace assembly into the casting position.

The operator next depresses the foot-lever with his right foot to lock the dies together and also the gooseneck in the casting position. A safety latch is at the same time disengaged so that the operator can shift a valve lever at the top of the machine with his right hand. This admits air into the top of the cylinder on the furnace unit to force the metal plunger down into the gooseneck for shooting the metal into the dies.

Solidification of the casting occurs almost instantly because most dies used on this equipment are water-cooled.

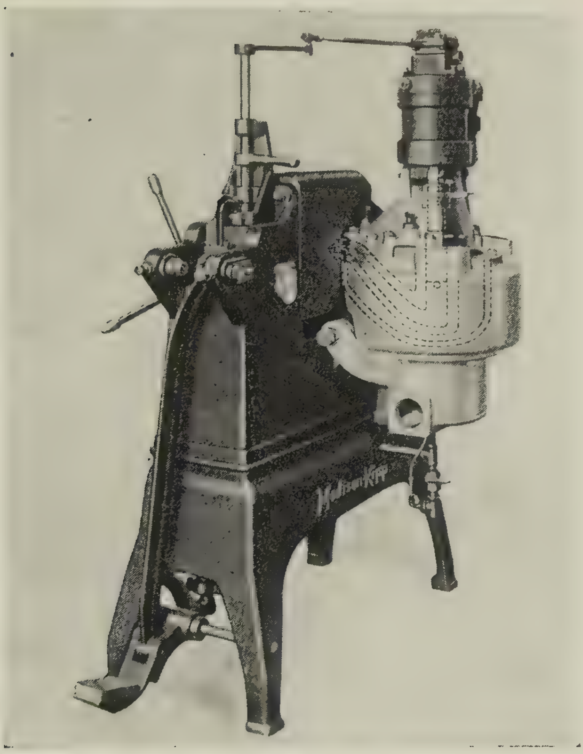


Fig. 8. Hand-, Foot-, and Air-operated "Kippcaster" Intended for the Production of Small Die-castings with Inexpensive Dies

The operator then returns the valve-shifting lever into its original position, depresses a lever at the foot of the machine to unlock the toggle mechanisms, and pulls the spider handwheel toward him to open the dies and eject the casting. The effective capacity of the standard gooseneck is 1 1/2 pounds of zinc per operation, but goosenecks of larger capacities can be provided. The standard dies for this machine are 6 inches long by 6 inches wide by 3 inches in total thickness, but larger dies can also be used.

A Model 215 Kippcaster is similar to Model 115 except that the dies are closed pneumatically in addition to the metal being forced into the dies by applying air pressure on a displacement plunger. There are also Models 315 and 415 of similar design with the exception that air pressure is applied directly on the molten metal instead of on a plunger. All of these models are intended for die-casting zinc-, lead- and tin-base alloys.

A Model 40 machine is used for die-casting aluminum, magnesium, etc. With this machine, the molten metal is ladled by hand from an auxiliary furnace into a well at the bottom of the machine. This well is then brought into the casting position underneath the dies, and when the dies have been locked, a high air pressure is applied on a plunger in the well to force the metal upward into the dies. There is also a Kippcaster Model 15 which is completely hand- and foot-operated, the plunger being actuated by hand as well as the dies and the gooseneck. This machine was designed for the production of limited quantities of die-castings.

A Model 6 machine, intermediate between the automatic machines and the Kippcasters, is equipped with a gooseneck having an effective capacity of 5 pounds of zinc. This machine has a Geneva mechanism for quickly moving the complete furnace assembly and for conveniently changing pots and goosenecks when there is a change in metal specifications.

Polak Die-Casting Machine.— The Polak die-casting machine (Fig. 9) is a type adapted to the die-casting or "pressure-casting" of brass, bronze and German silver. The comparatively high melting point of copper-base alloys and the injurious effect of this high temperature on the dies explains why the die-casting of alloys such as brass, on a commercial basis, has presented a much more difficult problem than die-casting alloys having considerably lower melting points.

The brass alloy at the time it is forced into the die of a Polak machine is semi-molten or in a plastic condition; con-

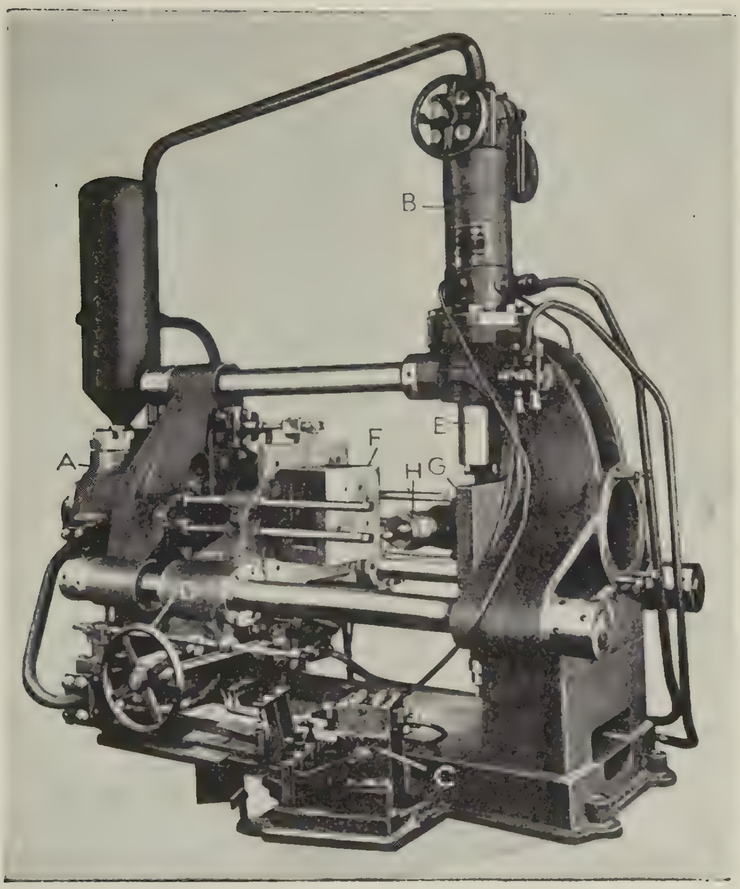


Fig. 9. Polak Die-casting Machine for the Production of Castings from Brass, Bronze and German Silver

sequently, the temperature is much lower than that of molten brass and the life of the die-casting dies (which frequently are expensive to make) is increased considerably. The use of semi-molten brass is made possible by forcing the metal into the die-cavity under a high pressure. Polak machines exert pressures on the metal ranging from approximately 3000 pounds per square inch to about 10,000 pounds per square inch.

General Features of Polak Machines.— The Polak die-casting machine is hydraulically operated and the casting operation is automatic. The closing and opening of the movable half of the die is performed by a small auxiliary cylinder. After the die is closed, a valve opens automatically, allowing water to enter the large closing cylinder *A* (Fig. 9) and then the locking pressure is applied. Cylinder *B* contains the piston or plunger *E* which exerts pressure upon the metal, forcing it into the die-cavity.

Polak die-casting machines are built either for using center-gate dies or split-gate dies. In the case of machines designed for center-gate dies, the plastic metal is ladled into a compression chamber in the housing of the machine itself and forced into the dies through a horizontal gate by a hydraulically operated vertical ram. With machines designed for split-gate dies, however, the charge of plastic metal for each casting is ladled directly into a well or chamber provided in the top of the dies themselves. The vertical ram of the machine descends into the die chamber to force the metal through a vertical gate into the die-cavities. Fig. 9 shows a machine of medium size designed for using split-gate dies.

The hydraulic movements of the machine shown in Fig. 9 are controlled through the foot-operated valve unit *C* and handwheel *D* which is connected to a second valve unit. The movable die is mounted on carriage *F* which is guided on two heavy rails in its movements to and from the stationary die. The latter is attached to the face of platen *G*. Water is the medium for obtaining the hydraulic pressure that actuates the movable carriage as well as the other automatic movements of the machine. A prefill cylinder mounted vertically on the left-hand end of the machine greatly reduces the amount of water under pressure that must be used for each opening, closing, and locking of the dies. This prefill cylinder also intensifies the pressure on the water that is admitted into it.

The metal, before being used, is melted to the liquid state in order to bring impurities to the surface where they may be removed readily. The auxiliary furnace from which metal is supplied to the compression chamber is placed near the machine and contains metal that is cooled down to the point where it is semi-molten or plastic. The melting furnace may be heated either by gas, oil or electricity. The oil-fired type is commonly used in European practice, but in the United States automatically controlled electric furnaces are favored. The normal consumption of water is one-half gallon per operation with the Type 450 machine and one gallon per operation with Type 500.

The Hydraulic Core-Pulling Attachments.—The hydraulic core-pulling attachments (like the one at *H*, Fig. 9) are interchangeably mounted on clamping plates conveniently located at both sides and underneath the stationary die-member, the necessary adjustments being facilitated by the provision of T-slots and swivel plates so that the cores may be pulled in any desired direction. Suitable couplings are used for connecting the piston rods of the attachments to the core pins; the necessary water connections are made by flexible copper tubing and nipples, no packing being employed. If required, hydraulic pressure can also be applied to the movable die through a telescopic tube. The movements of the cores and ejectors may also be derived from the return movement of the die-slide by means of adjustable trip dogs.

Modern Commercial Die-Casting Machines.—The tremendous increase in the use of die-castings in recent years is due to the fact that many parts and products can be produced more economically by the die-casting process. The production cost of die-cast parts is relatively low in a great many cases in comparison with other possible methods of manufacture; moreover, the quality of the product as determined by its accuracy, appearance or physical properties may either compare favorably with other manufacturing processes or be of a much higher order.

Manufacturers who can use die-cast parts may either purchase them from some firms specializing in die-casting or they may install die-casting equipment of their own. It is, of course, impossible to say which plan is the more economical because this not only depends upon the amount of die-casting required, but upon a number of other factors which should be considered in determining whether or not an investment in die-casting equipment is warranted.

The commercial die-casting machines now on the market cover a wide range of designs adapted to the production of parts ranging from the simplest and smallest to the largest and most intricate designs within the range of the die-casting process. A number of different commercial machines will be described. No attempt has been made to show all the different sizes and makes, but merely to feature representative designs which are now being used for producing the various classes of die-castings in many different lines of manufacture. The great advancement which has been made in die-casting practice is due not only to great developments in the design of die-casting machines, but also to the design of the dies and in adapting the design of the product itself to the die-casting process.

Small Machines for Die-Casting Lead-, Tin-, and Zinc-Base Alloys.—The Reed-Prentice Model "O" die-casting machine shown in Fig. 10 is designed for manual operation and will produce zinc alloy castings weighing up to 16 ounces at a maximum rate of 600 "shots" per hour. The maximum casting area for this size of machine is 7 1/2 square inches at 1500 pounds per square inch injection pressure.

The two hand levers on the front of the machine are used to operate hydraulic pilot valves. The lever on the left controls the valve for hydraulically closing the dies, the lever

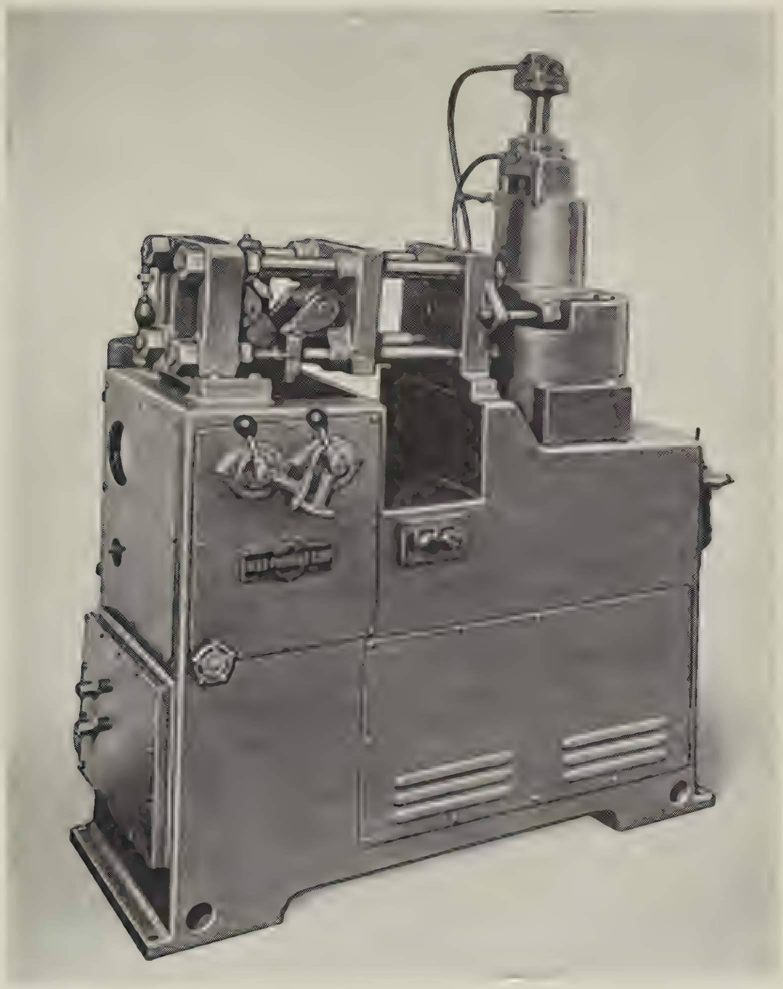


Fig. 10. Reed-Prentice Die-Caster for the Production of Small Castings of Low Melting Point Alloys.

on the right controlling the injection of metal from the gooseneck into the dies. As may be seen in Fig. 10, the right-hand lever cannot be moved into position for making the "shot" unless the die-closing lever on the left is in the closed die position, thus moving the interlocking lobe out of

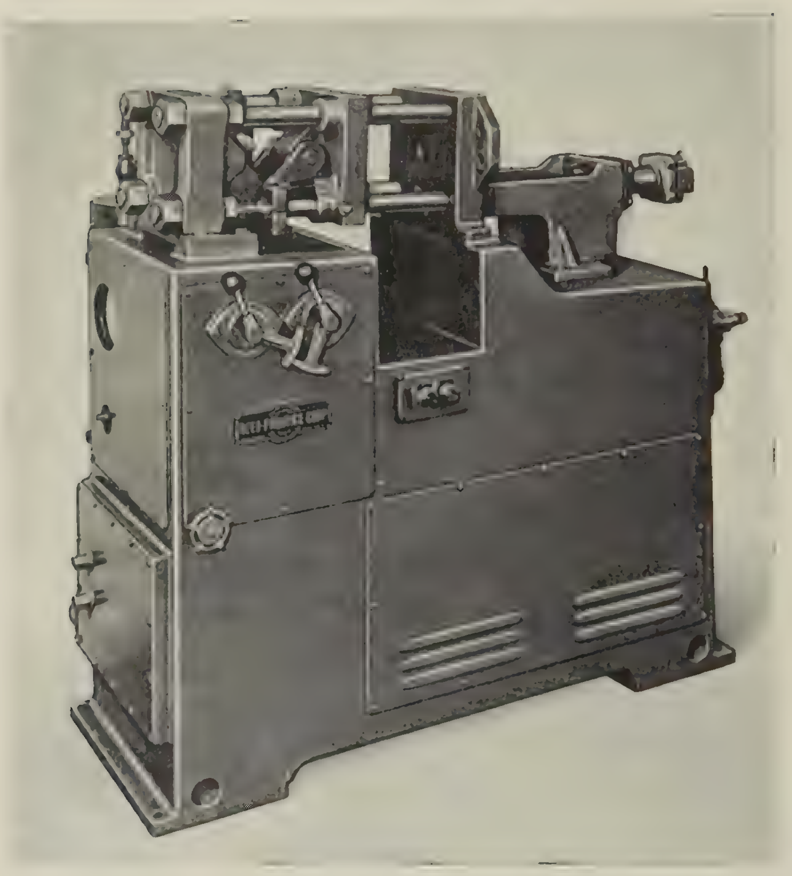


Fig. 11. Reed-Prentice Cold Chamber Die-Caster for Small Aluminum, Magnesium, or Brass Alloy Castings.

position. In a similar manner, the dies cannot be opened until the "shot" lever has been moved back to its original position.

This machine may be converted to cast aluminum, magnesium, or brass alloys by removing the gooseneck arrangement and replacing it with a high pressure cold chamber attachment as shown in Fig. 11. With this arrangement, a separate melting pot located in the vicinity of the machine is required, since cold chamber machines require hand ladling of molten metal from pot to injection chamber.

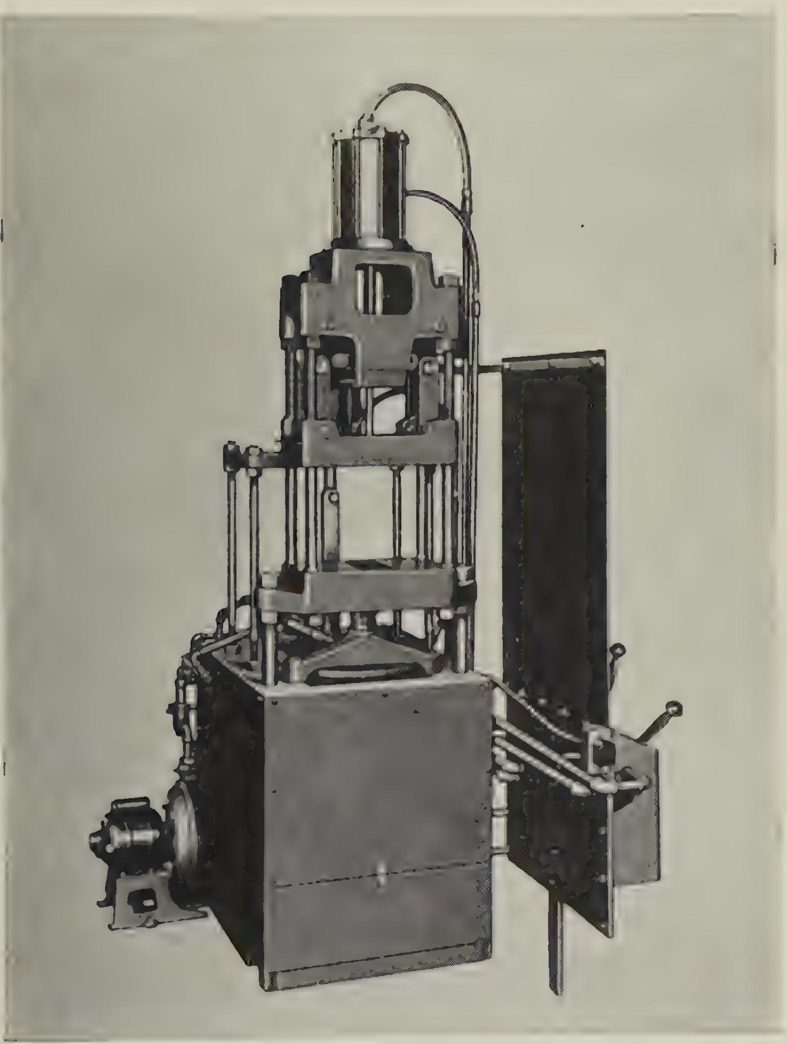


Fig. 12. Kux Vertical Die-Casting Machine for Producing Zinc, Lead, or Tin Alloy Castings Having Inserts.

Machine for Casting Around Inserts.—The vertical type of air-operated die-casting machine, for zinc, lead, or tin alloys, shown in Fig 12 is specially designed for the production of castings having inserts. The construction of the machine is such that the dies are opened and closed vertically to provide for easy placement of inserts in the lower die prior to making a "shot." Opening and closing of the die halves is accomplished by means of a toggle mechanism located at the top of the machine which is actuated by means of an air cylinder. The plunger-gooseneck unit is mounted on the melting pot immediately below the lower die-plate, the plunger being operated by a second air cylinder. The operation of both air cylinders is controlled by the movement of the two air-valve hand levers shown on the right side of Fig. 12. These levers are mechanically interlocked to prevent making a "shot" while the dies are open. Built into the base of the machine is a gas, oil or electrical heating unit for melting the charge in the pot. The maximum weight of metal, including gate, that can be cast in one "shot" is 3 pounds of zinc and the capacity of the melting pot is 250 pounds of zinc. Air pressure required to operate the air cylinders is 125 pounds per square inch maximum and the force available for locking the dies is 25 tons. A mechanism

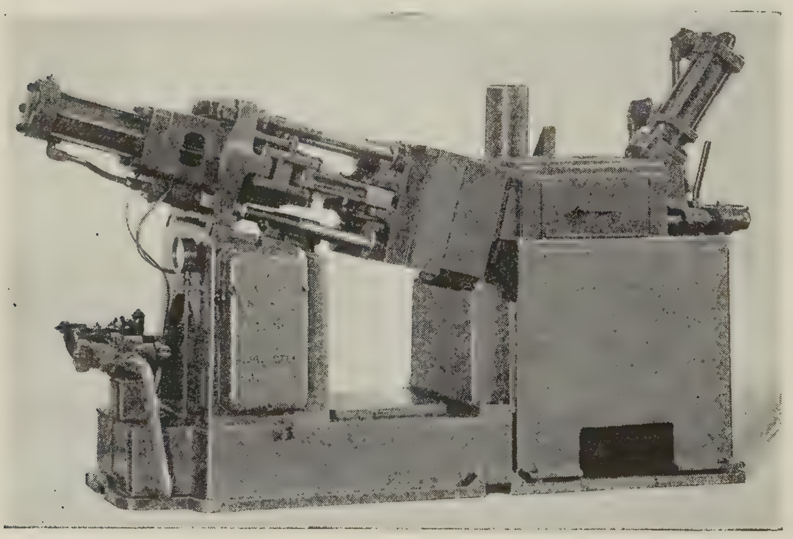


Fig. 13. Reed-Prentice Hydraulically Operated Automatic Die-Casting Machine.

that automatically ejects the casting as the die opens is located above the top die-plate.

Hydraulically Operated Automatic Die-Casting Machine.—The automatic, hydraulically operated die-casting machine, Fig. 13, is equipped with an electric timing mechanism which allows the operator to set the machine for any predetermined period from 0 to 20 seconds for the solidifying of castings. This machine can be arranged for automatic or manual operation, separate control levers being provided for this purpose. This machine is also designed so that it is impossible to "shoot" the metal into the dies until they are securely locked. An electric safety mechanism, as well as a pilot valve mechanism, eliminates any chance of "shooting" the metal when the dies are open.

When the dies are constructed for automatic ejection, the castings are ejected through holes in the center of the die-plate as the dies open. This permits the castings to drop into a box or chute at the bottom of the die from which they can be removed automatically. The die-plates are planed on four sides for the application of core-pulling attachments. The removable die-plate is bronze-bushed and has oiling facilities.

General Features of the Hydraulically Operated Machine.—The general arrangement of the machine shown in Fig. 13 is illustrated by the diagram, Fig. 14. The movable half of the die-casting die is attached to plate *A* and the stationary half is in contact with nozzle *D* through which the metal is forced when making a casting. This plate *A* slides on four rods *B* and is moved to and from the closed or casting position through a toggle link mechanism connected by a rod with the piston in the hydraulic die-closing cylinder *C*.

When the die is in the casting position, molten metal is forced through nozzle *D* by plunger *E* connecting with the hydraulic cylinder *F*. When plunger *E*

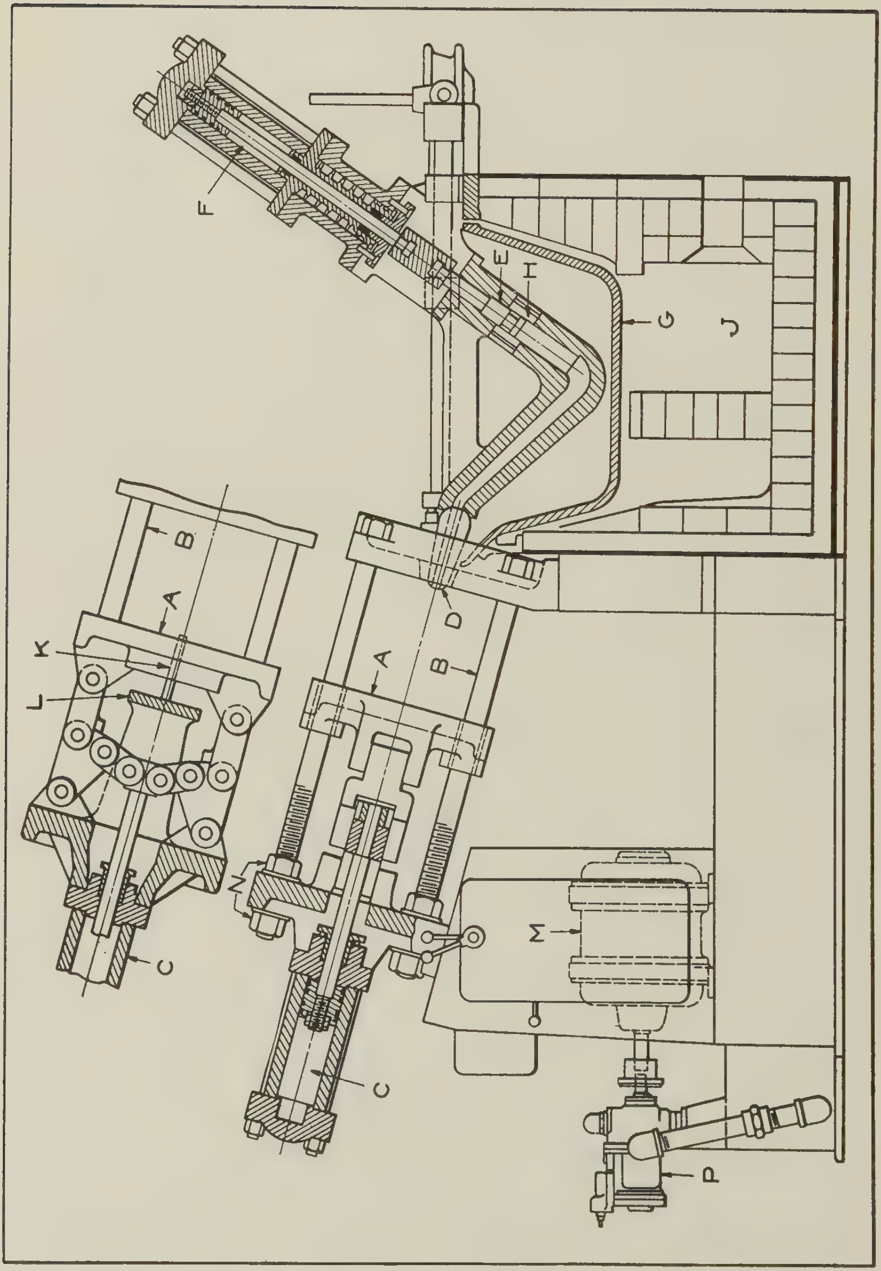


Fig. 14. Diagram Showing General Features of Reed-Prentice Machine Shown in Fig. 13.

is withdrawn, as shown, molten metal flows from pot *G* through openings *H;* then the downward stroke of plunger *E* forces the metal through the nozzle *D* into the die-cavity. The furnace *J* may be arranged either for oil or gas heating. After "shooting" the metal into the die, there is a dwell to permit the metal to solidify, the length of time being automatically controlled by an adjustable electric timing device. When the plate *A* and the movable half of the die is withdrawn, the casting which remains in the movable section comes into contact with pins *K* arranged to suit the die and projecting from the stationary ejector-plate *L*.

Hydraulic pressure is supplied by a pump *P* driven by motor *M*. When the machine is manually operated, one lever closes the die and another controls the operation of plunger cylinder *F*. These two levers are interlocked so that it is impossible to operate the metal plunger until the dies are securely closed. For automatic operation, it is only necessary to move a single lever which causes, first, the closing of the die; second, the downward movement of the metal plunger forcing the metal into the die-cavity, after which the electric timing device controls the dwell or solidifying period which ranges from zero to 20 seconds. At the end of this dwell, the machine automatically goes through the reverse cycle and is ready for the next operation.

The head *A* is shown in the closed position and adjusted to provide the maximum die space. The die space is changed by moving the whole toggle assembly forward on the tie-bars and locking it in position by means of nuts *N*.

Machines for Die-Casting Aluminum, Magnesium, or Brass Alloys.—High melting point alloys such as aluminum have a tendency to dissolve the component parts of die-casting machines if the molten metal remains in contact with these parts for any appreciable length of time and thus to contaminate the casting alloy. For this reason, cold chamber

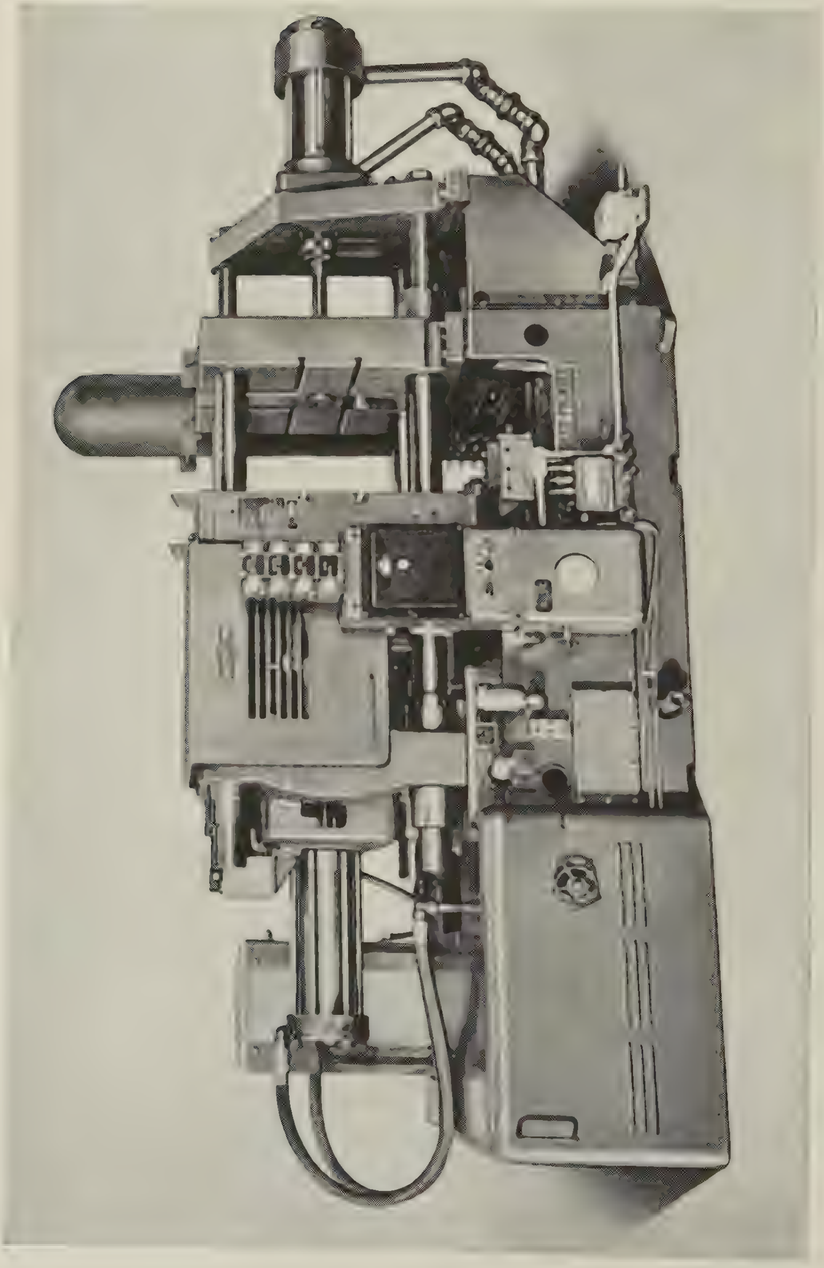


Fig. 15. Reed-Prentice Cold Chamber Die-Casting Machine for Producing Large Size Aluminum, Magnesium, or Brass Castings.

type machines are preferred for use in die-casting aluminum and other high melting point alloys.

In the cold chamber type of die-casting machine, the metal to be cast is held in a melting pot separate from the machine. The metal is hand ladled from the pot into an opening in the injection cylinder immediately prior to making a shot, thus reducing the time of contact between molten metal and injection chamber. The contamination of the alloy is therefore considerably reduced.

The machine in Fig. 15, manufactured by the Reed-Prentice Corporation, is a representative type of modern cold chamber machine. It is arranged for both manual or semi-automatic operation. For semi-automatic operation, the dies are closed manually by pressing the buttons on the control panel. The operator then ladles the metal into the pouring slot in front of the injection plunger and then steps on the foot switch to shoot the plunger forward. The remainder of the cycle is automatic and is controlled by an adjustable electrical timing device. The plunger remains forward and when the dies open, it travels an additional distance forward to eject the slug before returning to its starting position.

To manually operate the machine the push buttons on the control panel are used. The upper two open and close the dies. The next lower two actuate the plunger. An electrical interlock eliminates the danger of injecting the metal until the dies are securely closed. Ejection of the casting takes place automatically when the dies open. Both die-plates on this machine are finished on the side to provide for the mounting of core-pulling attachments.

The forward stroke of the plunger for forcing the metal into the die cavity is accomplished with unusual rapidity and force through the delivery of oil at high pressure by an accumulator located at the right-hand end of the machine as seen in Fig. 15. The accumulator is always open to receive oil through a check valve from a high pressure pump in the machine, but a control valve allows the delivery of the high pressure oil from the accumulator to the plunger only during the short period of the forward stroke. The accumulator is charged with nitrogen, this gas being used instead of air because if air was employed, oxidation of the oil at the high pressures involved would tend to corrode the valves, pumps, etc. Also, in the event of any leakage, there would be the danger of an inflammable mixture. Neither of these objections exists when nitrogen is used. The capacity of the accumulator is such that there is only a small drop in the hydraulic pressure as each shot is made. Fig. 16 shows schematically the stages in the production of an aluminum, brass, or magnesium die-casting using a cold chamber machine. The article being cast is of cup form, two

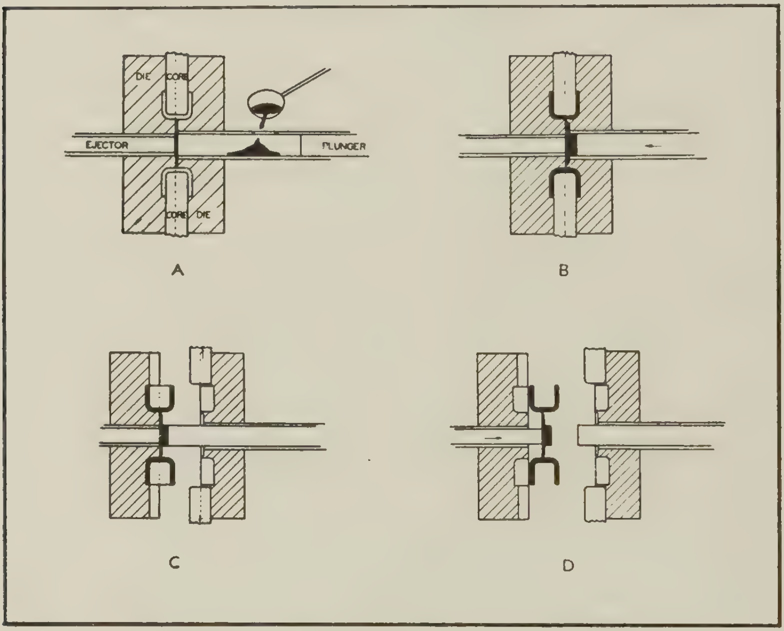


Fig. 16. Stages in the Production of Castings by the Cold Chamber Process: (A) Dies Closed, Cores in Position, Metal Hand Ladled Into Cold Chamber; (B) Plunger Moving Forward to Force Metal Into Die; (C) Dies Opening, Plunger Following the Moving Die; (D) Plunger Retracted, Ejector Operating to Eject Casting from Movable Die.

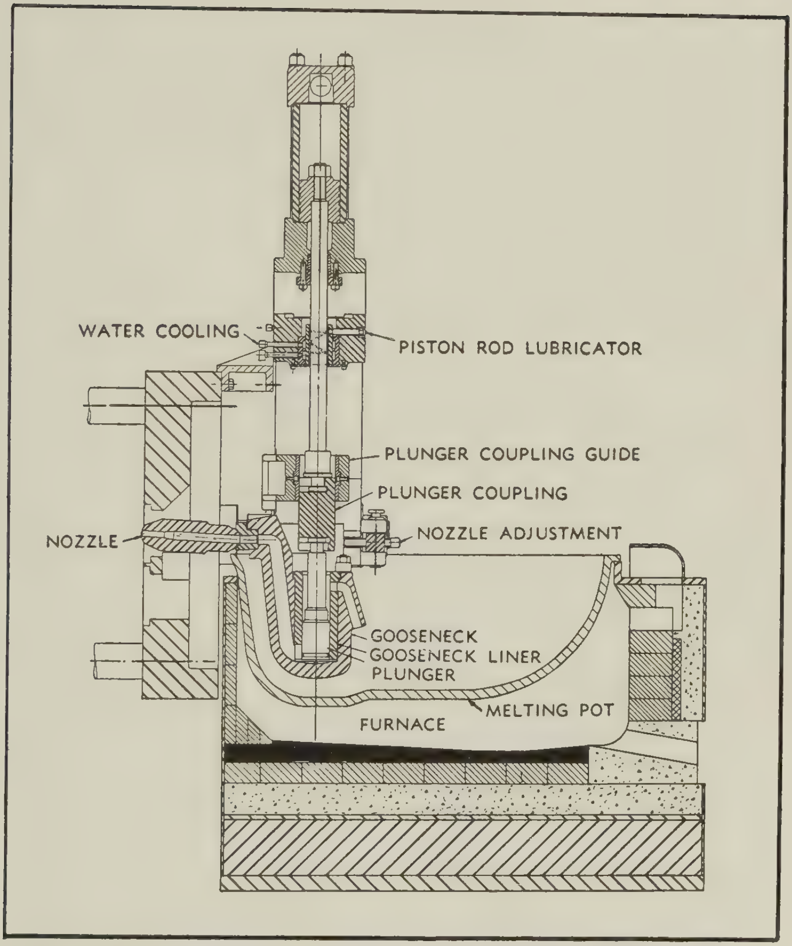


Fig. 17. Gooseneck and Furnace Arrangement Used to Convert Cold Chamber Machine Shown in Fig. 15 for Casting of Zinc-, Tin-, or Lead-Base Alloys.

cups being produced per cycle. Fig. 16-A shows the dies closed with cores in position before the molten metal is ladled in. The foot pedal is depressed to operate the plunger, after which the sequence of operations is automatic. In Fig. 16-B the plunger has forced the molten metal into the die. After this, a period is allowed for cooling and the cores are withdrawn from the casting before opening the dies.

In Fig. 16-C the back half of the die has moved away from the front half, the plunger following the moving die and ejecting the casting from the stationary die. The motion continues until the ejector comes into operation and ejects the casting from the die as shown in Fig. 16-D. For different injection pressures the diameter of the injection plunger and its cylinder are varied. For example, on the 1 1/2G machine shown in Fig. 15, the machine will cast 4 1/4 pounds of brass at a pressure of 16,000 pounds per square inch or 11 3/4 pounds at a pressure of 5700 pounds per square inch by using different diameter plungers and cylinders.

The No. 1 1/2G cold chamber machine shown in Fig. 15 may be converted to a No. 1 1/2 gooseneck machine for casting zinc-, tin-, or lead-base alloys by removing the cold chamber mechanism and replacing it with a gooseneck and furnace arrangement. Fig. 17 shows the arrangement of the furnace and gooseneck used for casting these low melting point alloys.

In Figs. 18 through 23, cold chamber machines of the type manufactured by the Lester-Phoenix Corp., the Kux Machine Co., the Hydraulic Press Manufacturing Co., the Loewy-Hydropress Co., the Cleveland Automatic Machine Co., and the Lake Erie Engineering Corp. are shown.

Using Hydraulic Presses for Die-Casting.—In some plants, vertical-type hydraulic presses are used to produce certain types of die-castings. A description of how one particular casting is produced by using such a press will indicate the field of application.

In the production of electric motors at the Buffalo plant of the Westinghouse Electric Corp., one of the most interesting operations consists of die-casting aluminum on the rotors to fill the helical slots provided by the laminations, to form solid end rings of aluminum at both ends of the laminated section, and to form fan vanes on one of the end

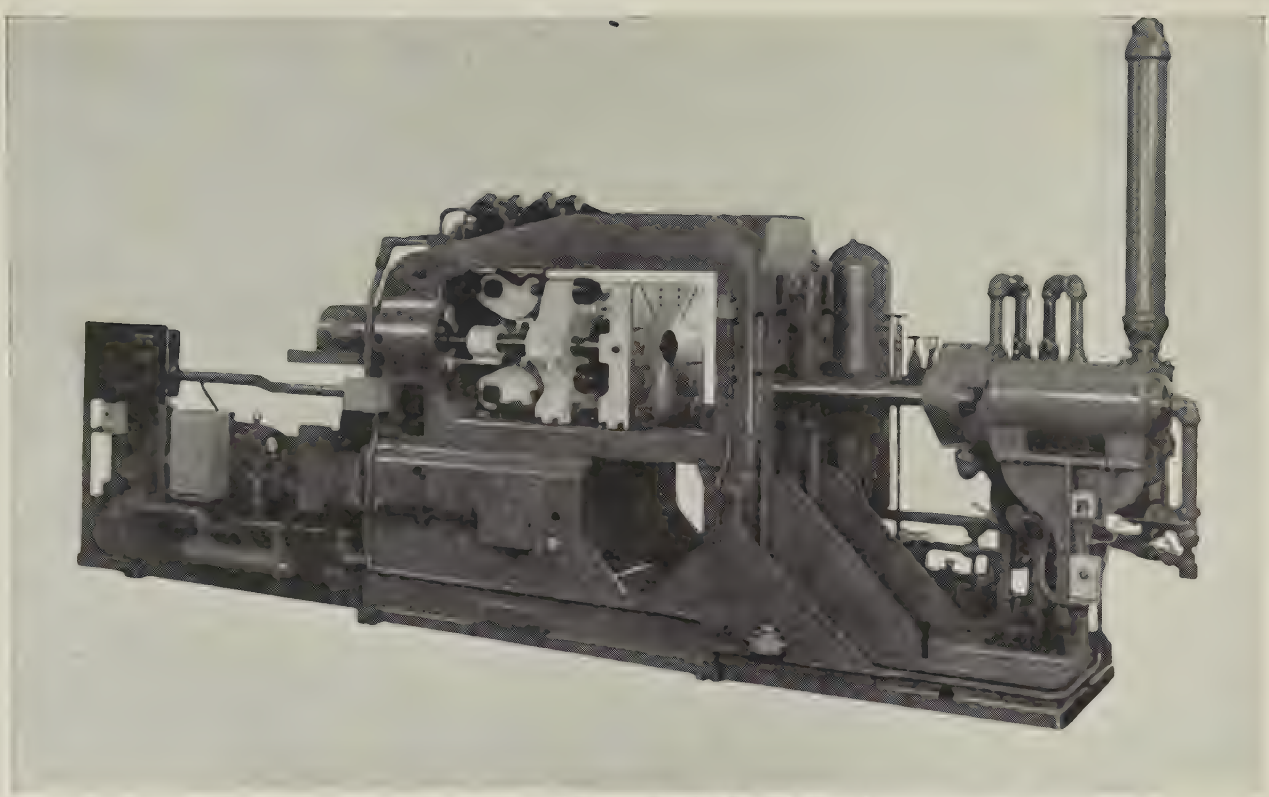


Fig. 18. Lester-Phoenix Cold Chamber Die Casting Machine Used for Casting Aluminum, Brass, and Magnesium These Machines Utilize Beam-Type Frame Construction in Contrast to the Tie Rods Used on Other Machines

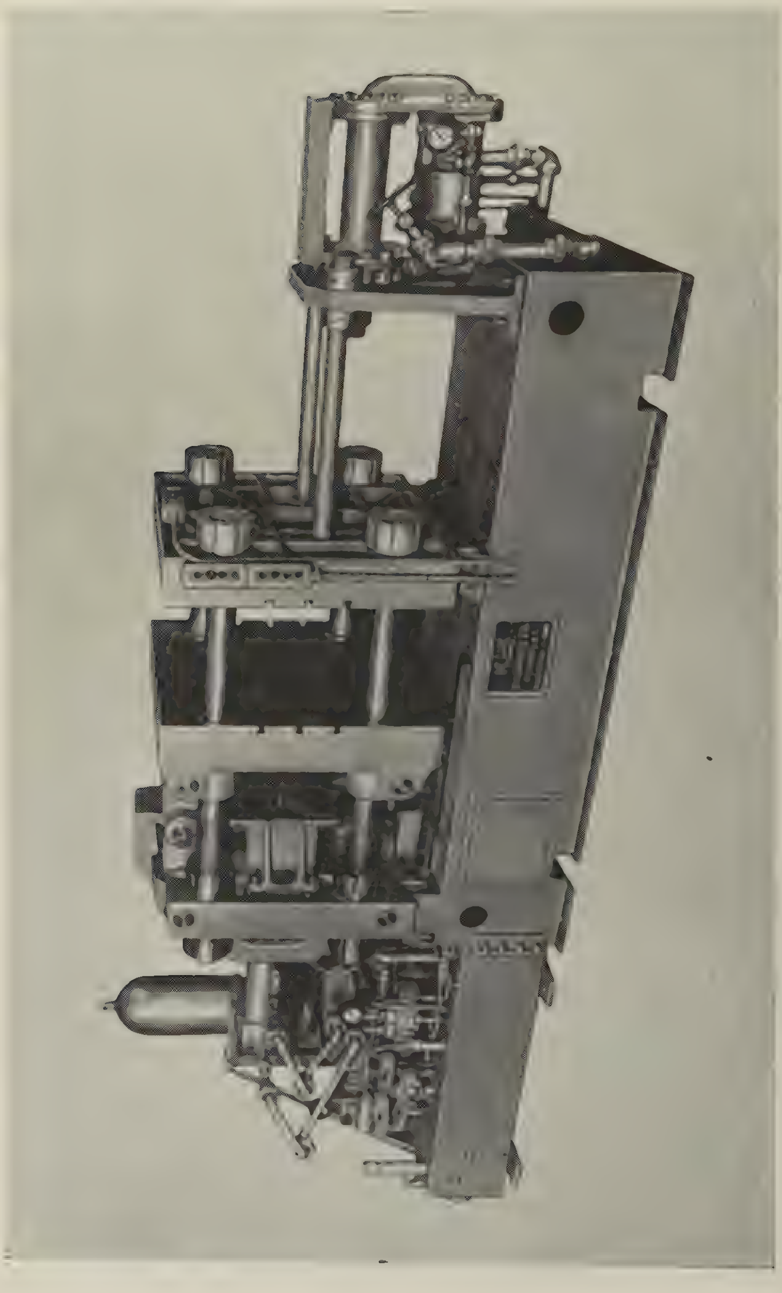


Fig 19 Large Size Cold Chamber Die-Casting Machine Manufactured by Kux Machine Company.

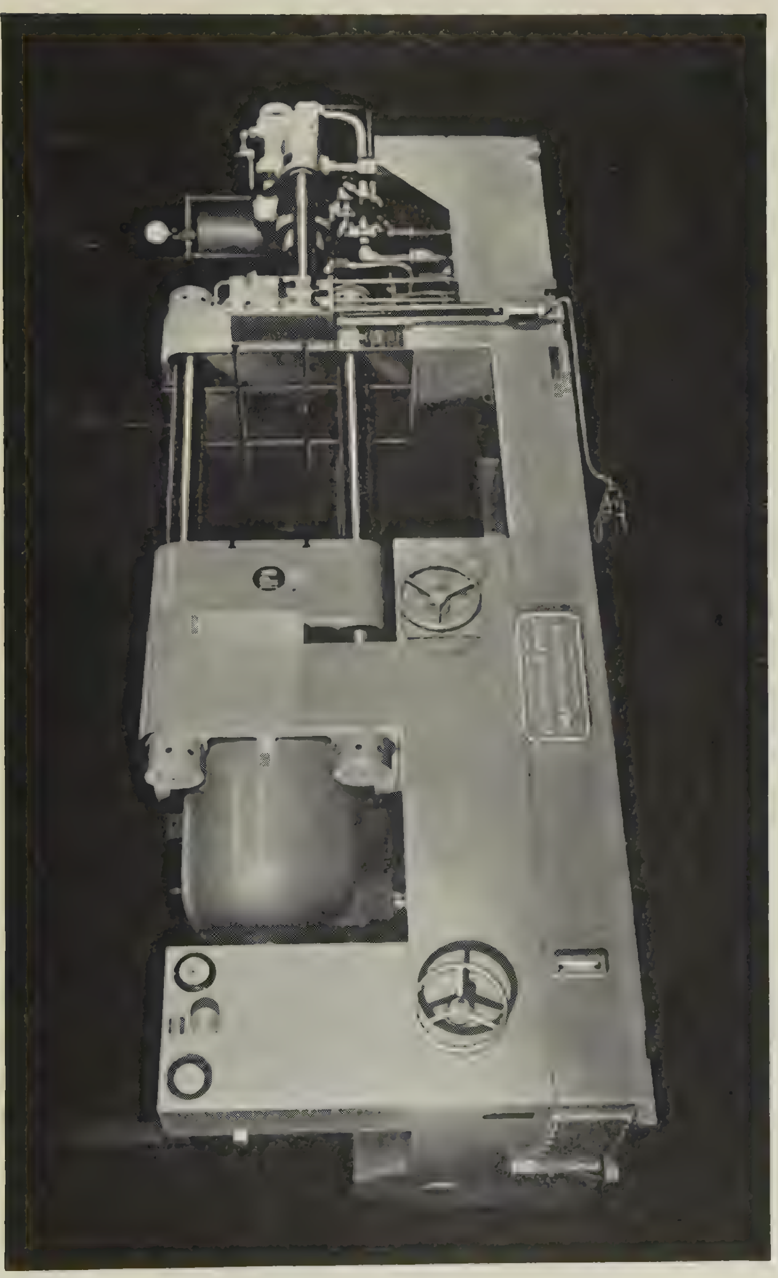


Fig. 20. H-P-M Model 400-AB Cold Chamber Machine that is Entirely Operated by Hydraulic Pressure.

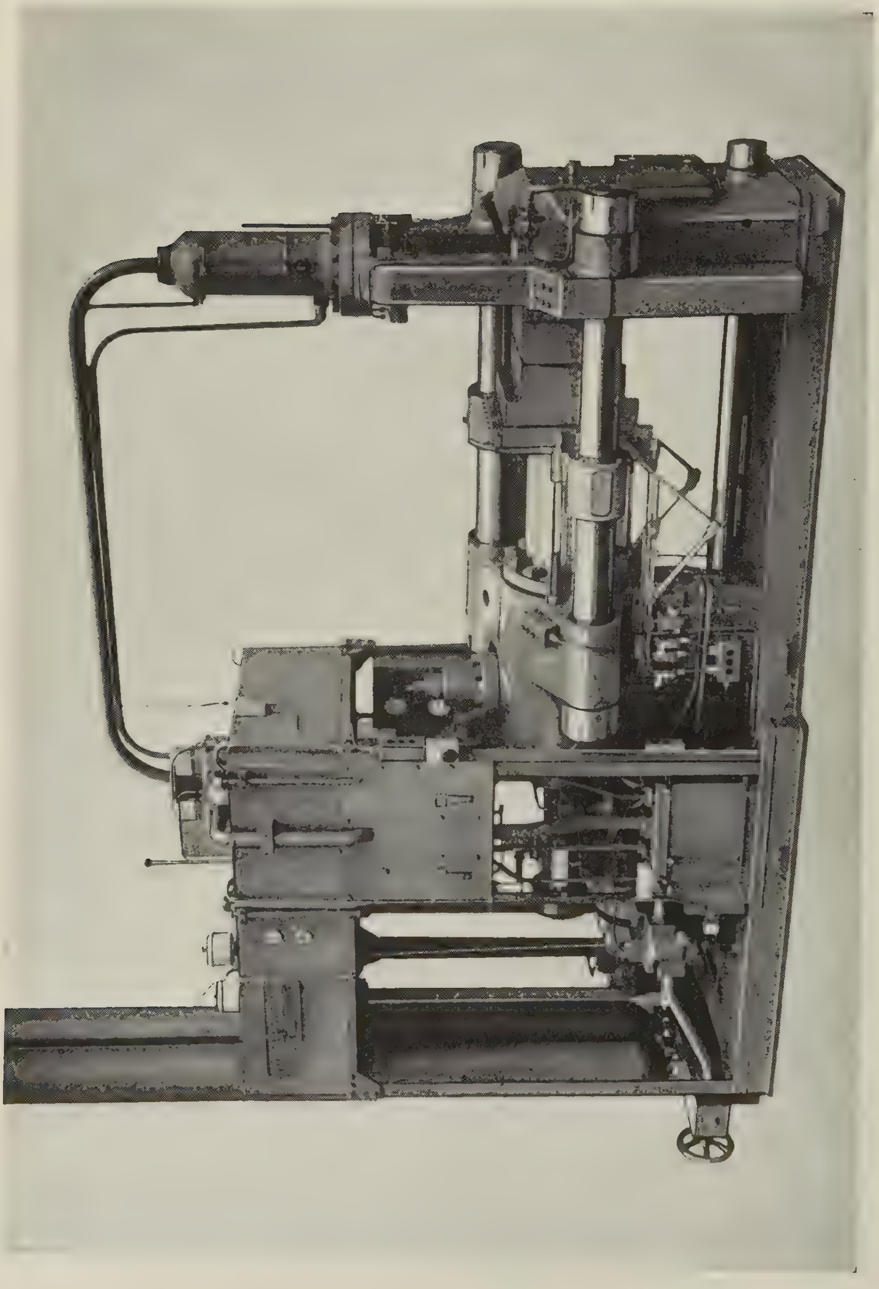


Fig. 21. Hydrocast No. 3 Hydraulic Cold Chamber Die-Casting Machine Manufactured by Loewy-Hydropress. This Completely Hydraulic Machine is of the Vertical Cold Chamber Type.

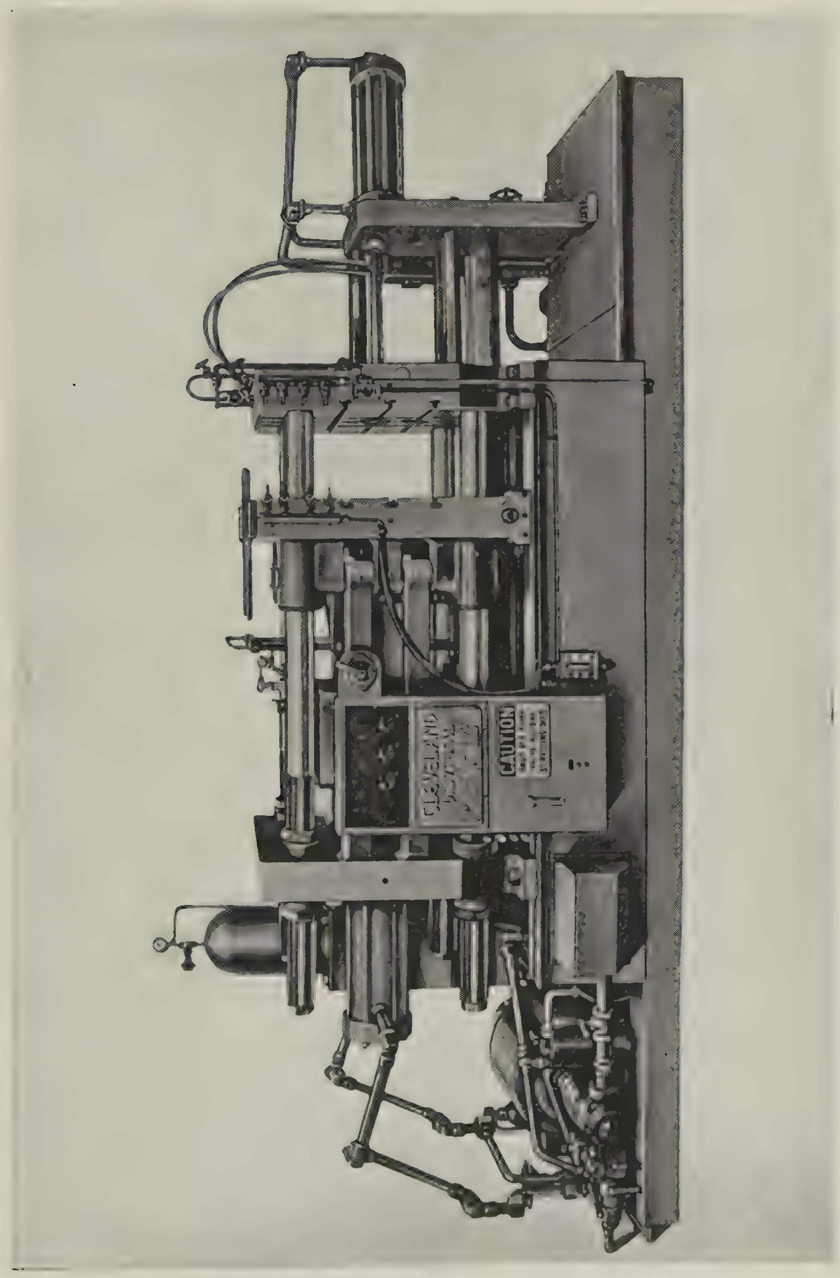


Fig. 22. Cleveland Automatic Cold Chamber Machine for Casting Aluminum, Magnesium, or Brass.

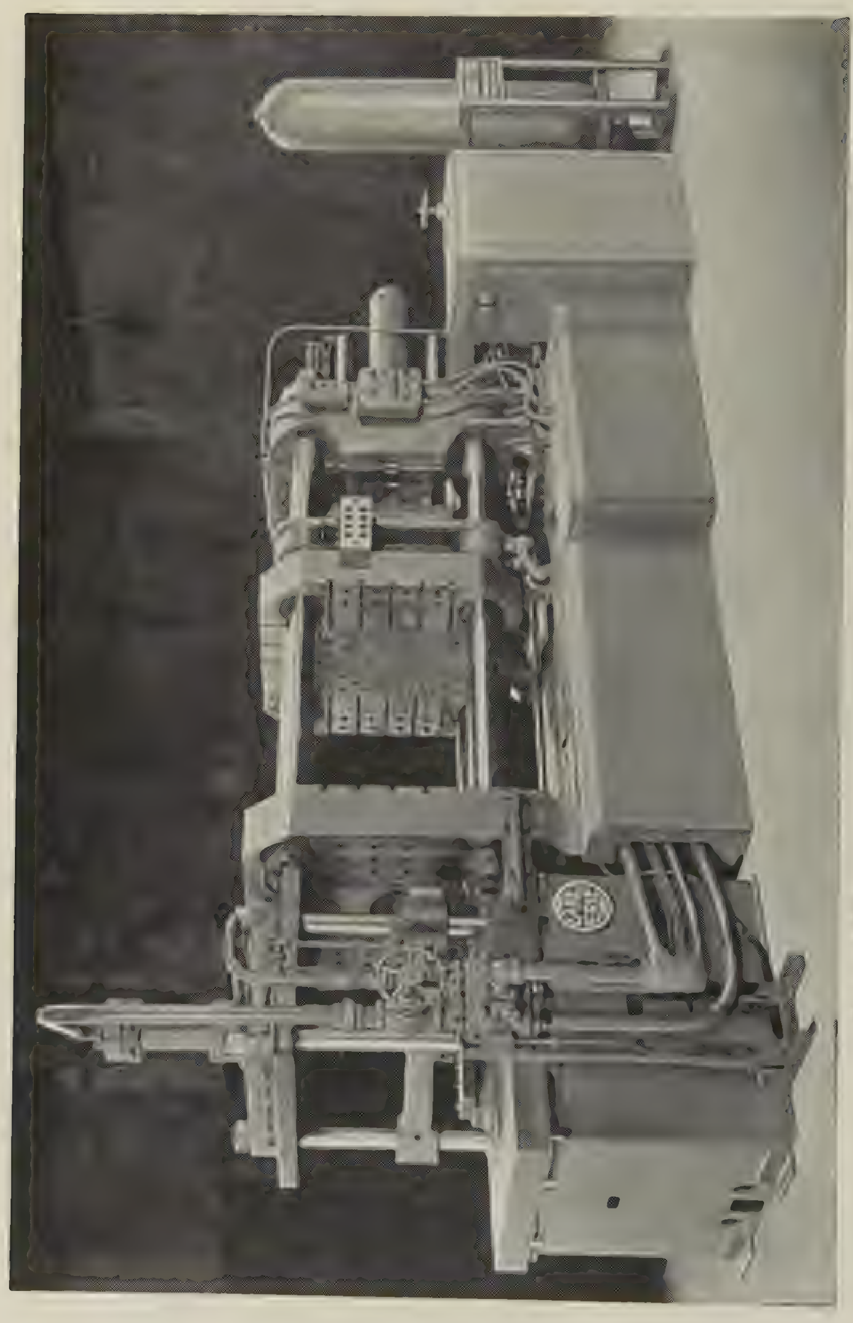


Fig. 23 Lake Erie Die-Casting Machines of the Type Shown are Built in Models Ranging from 100 to 1000 Tons Capacity.

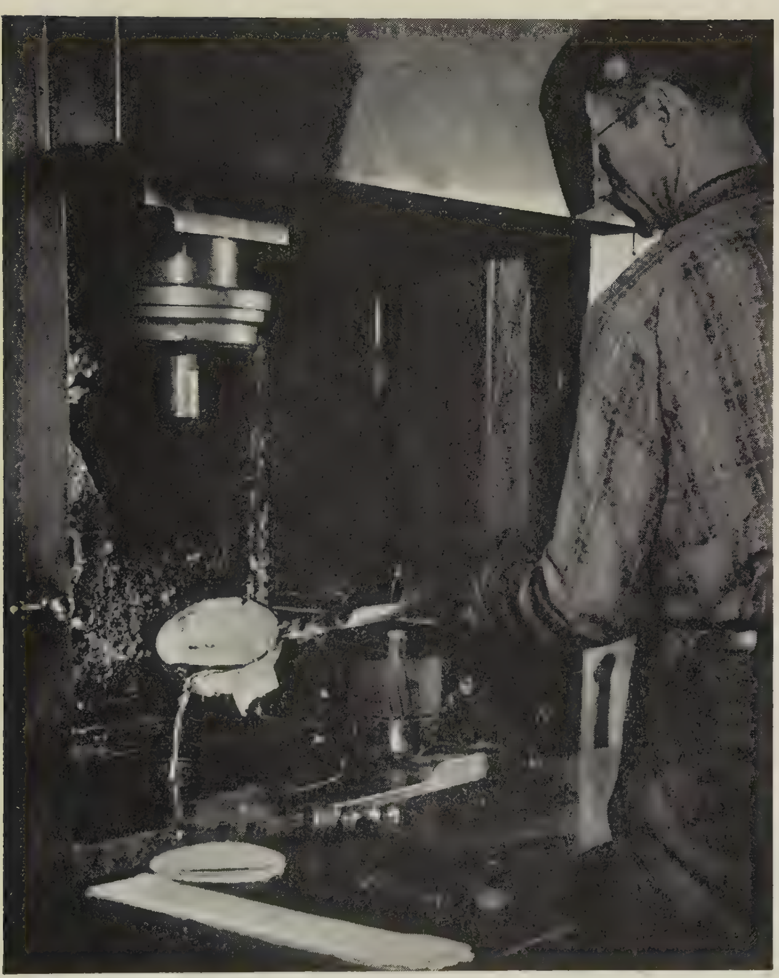


Fig. 24. Molten Aluminum is Ladled into a Pot in the Bed of the Hydraulic Press, Ready for Die-Casting the Aluminum through the Slots of Rotor Laminations. End Plates and Fan Vanes are Also Formed on the Rotor in This Operation.

rings. The die-casting operation locks the laminations permanently in a slightly staggered relation, so as to insure the desired helical arrangement of the slots.

At the beginning of a die-casting operation, a ladle of molten aluminum dipped from an adjacent pot type furnace is poured into the pot of the Lake Erie hydraulic press, as shown in Fig. 24. Then, a stack of laminations, mounted on an arbor or skewed sleeve and on a cylindrical plug, as shown at the right, is placed in the mold or die with the bottom edge of the laminations about 1/4 inch below the press platen. The plug on which the laminations are mounted has a series of shallow vertical slots in it, which serve as gates in the die-casting operation.

A disk of asbestos slightly larger than the pot or injection cylinder diameter is placed in the pot on top of the injection piston before ladling the aluminum into the pot. The asbestos disk performs three functions: (1) It acts as an insulator to prevent chilling the molten aluminum when it comes in contact with the water-cooled pot and piston; (2) it assists in preventing the erosion that normally results when molten aluminum comes in contact with a cast-iron pot liner and piston; and (3) it serves as a gasket to seal off any clearance between the cylinder and the piston.

In Fig. 25, which shows a cross-sectional view of the die-casting mold or die, the pot in which the molten aluminum is poured is indicated at *A*. The plug is shown at *B*, the arbor on which the laminations are mounted at *C*, and the space occupied by the laminations at *D*.

When the rotor assembly has been positioned, as seen in Fig. 26, and the operator pushes buttons to start the operation of the hydraulic press, the cylinder liner *E*, Fig. 25, which is entirely surrounded by a water jacket *F*, descends under power supplied by the upper hydraulic ram and encloses the rotor. This provides an upper die member for the operation. Then a guard or screen is lowered at the front of the press to prevent the molten metal from spattering on the operator during the die-casting operation. An interlock prevents operation of the injection piston if the guard is not in place.

Plunger *G*, operated by the lower hydraulic cylinder of the press, is next actuated upward to force the molten alu-

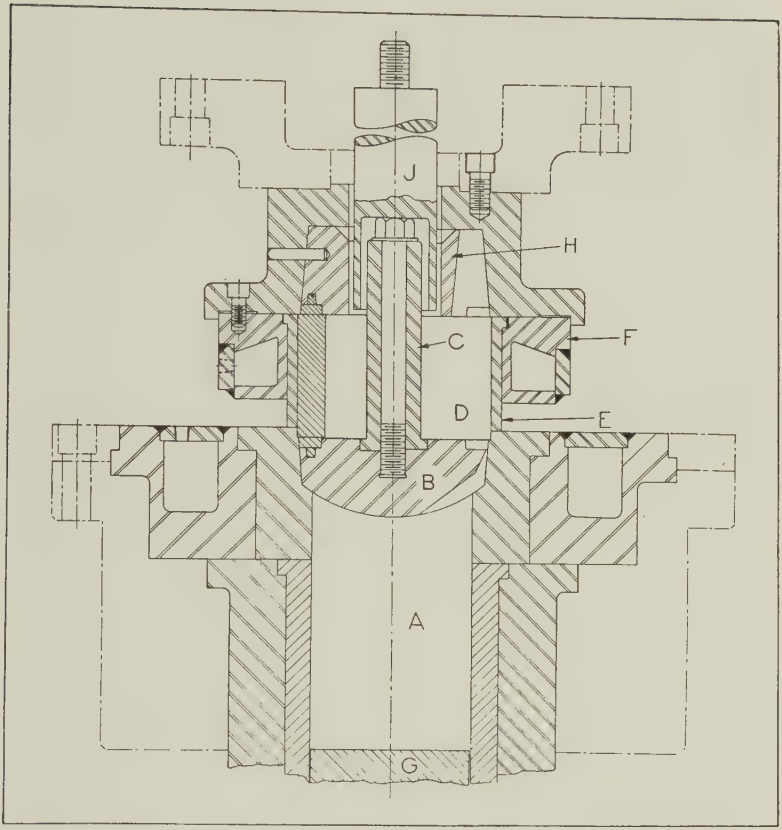


Fig. 25. Cross-sectional View of Die Equipment Employed in Casting Aluminum on the Rotors to Fill the Lamination Slots and to Form End Plates and Fan Vanes on the Laminations.

minum past plug *B* up through the slots in the laminations and into the slotted ring *H* which forms the top end ring of the assembly and its fan vanes. At the same time, the bottom end ring of the rotor assembly is formed as molten aluminum is forced into a step that runs along the top outer edge of plug *B*.

After the operation has been performed as described, the die members are held closed for about fifteen seconds to permit the cast metal to solidify. Then the upper press ram is automatically raised. Knock-out bar *J* remains stationary

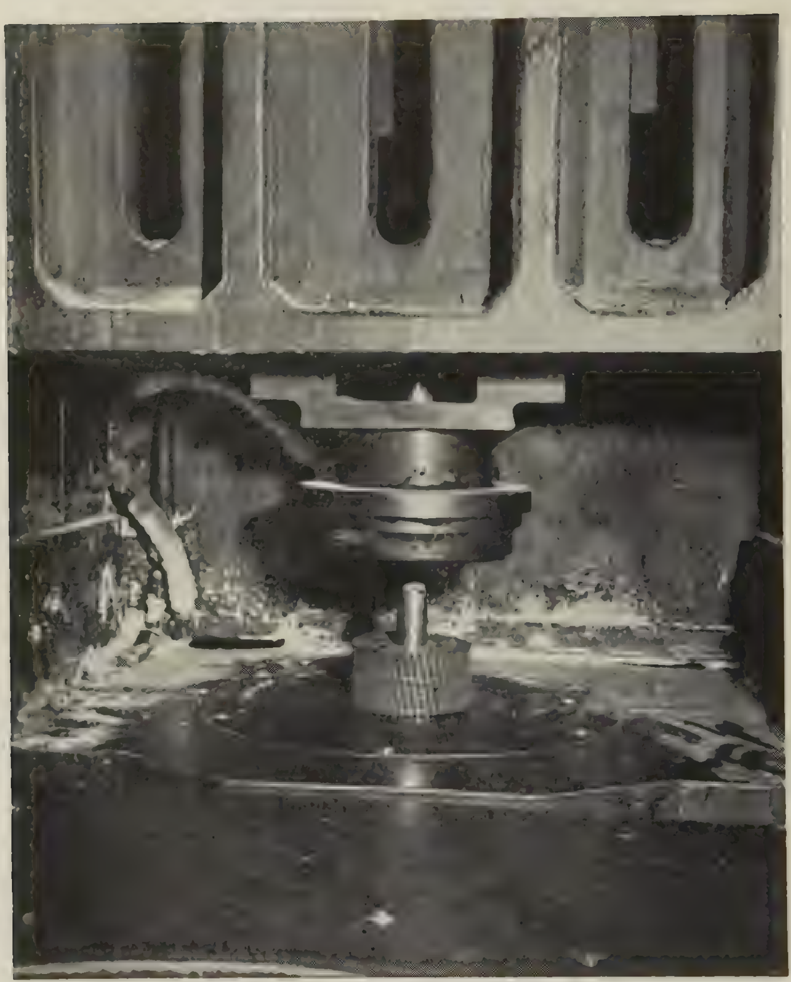


Fig. 26. Stack of Rotor Laminations in Place on Hydraulic Press with Laminations Held in Proper Radial Relation to Each Other by a "Skewed" Sleeve which Insures Desired Helix Angle of Lamination Slots.

momentarily to strip the rotor assembly from ring *E*. Then plunger *G* makes a short upward movement to strip the rotor assembly from the bottom die member. The excess metal in cylinder *A* forms on the bottom of plug *B* as a "pancake," which is easily knocked off by the machine operator and remelted.

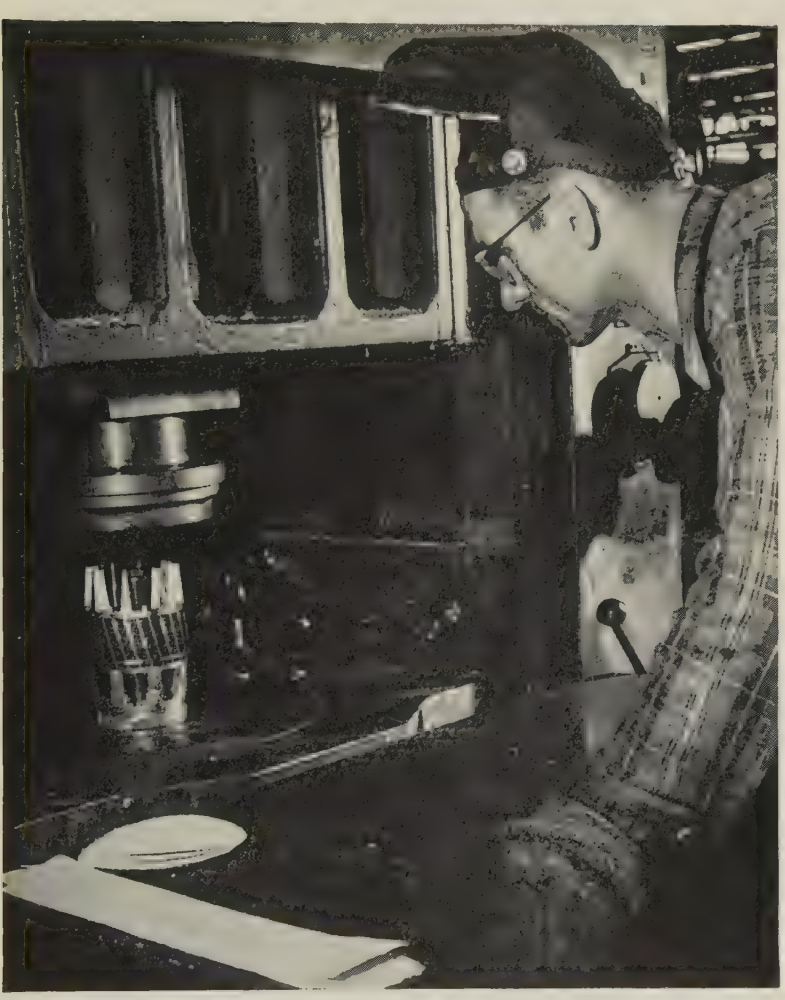


Fig. 27. View of Hydraulic Press at End of Rotor Die-Casting Operation, showing Rotor and Its Supporting Plug in Raised Position to Facilitate Removal of Work.

The pressure employed to inject the molten aluminum is 35 tons, while a pressure of 75 tons is applied by the upper cylinder and piston to clamp the dies closed against the action of the bottom cylinder and piston. However, the machine has a capacity for applying a pressure of 100 tons for the injection and 150 tons for clamping. The upper ram has a total stroke of 24 inches, and knock-out bar *J* has a movement of 6 inches relative to ring *E*. The piston in the lower cylinder has a maximum stroke of 7 inches. The die members with which the molten aluminum comes in contact are made from molybdenum steel.

Alloys for Die-Castings

Any metal intended for die-casting purposes must flow readily in the molten state, so that it can be forced under pressure to all sections of the die-cavities. In cooling, the metal must form smoothly, so as to prevent as far as possible the necessity of subsequent machining operations.

Alloys of aluminum, copper, lead, magnesium, tin, and zinc can be die-cast successfully. Those with the lowest melting point, such as lead, tin and zinc, are the easiest to cast, because there is less wear and tear on the dies. Good machine steel, not even heat-treated, can be employed for dies used to cast parts from the low-temperature alloys, whereas heat-treated alloy-steel dies are necessary for casting parts from aluminum and copper alloys.

Zinc, aluminum, and copper alloys are the most popular because of their properties. The accompanying tables lis the compositions and properties of the most generally use die-casting alloys.

Zinc-Alloy Die-Castings.—The applications of zinc die-castings seem almost endless. They have proved satisfactory for many automobile and machine parts; for ornamental purposes; typewriter frames, telephone parts, gasoline pumps, clock cases, washing-machine gears, small motor end-housings, door handles, and thousands of other applications. Zinc castings should not be exposed to high temperatures because of their low melting point, which is about 725 degrees F.

Practically any type of commercial finish can be applied to zinc castings after a light polishing operation. They can be electroplated with chromium, nickel, copper, brass, bronze, gold, and silver, or they can be coated with paints, varnishes, lacquers, and enamels.

Zinc-Base Die-Casting Alloys.—Zinc-base alloys are easy to cast, are low in cost compared to other die-casting alloys, and have good physical properties at normal temperatures. They are highly fluid at casting temperatures and may be cast in thin sections at relatively low injection pressures. Because of the low injection pressures required, it is possible to use smaller machines for zinc castings than for aluminum castings of the same size. The low casting temperature of zinc alloys results in a minimum of die wear and permits the use of relatively inexpensive steels in the construction of the dies.

The alloys shown in Table 1 are those most commonly used for die-casting. Both alloys are alike in composition except that alloy XXV contains about 1 per cent copper to increase the hardness and strength of the alloy. The presence of copper in excess of this amount tends to cause loss of impact strength and to reduce dimensional stability on aging.

Zinc alloys contain a small percentage of magnesium to provide increased stability of the physical properties with respect to aging. However, the presence of magnesium in amounts beyond the established limits tends to make these alloys hot short.

The presence of aluminum in the amounts specified reduces sticking of the casting to the die and improves the physical properties of zinc alloys in addition to reducing the amount of dissolved iron in the zinc.

The presence of tin, lead, or cadmium in these alloys results in subsurface corrosion. It is, therefore, of prime importance that the amounts of these elements should not exceed that specified in Table 1.

Aluminum-Base Alloys for Die-Casting.—Aluminum die-casting alloys possess the advantages of comparatively high tensile strength, light weight, resistance to corrosion and ability to take a good polish and to hold it under normal atmospheric conditions. These advantages adapt them to

Table 1. Composition and Properties of Zinc Die-Casting Alloys*

Designation	ASTM	XXIII	XXV
	SAE	903	925
	The New Jersey Zinc Co.	Zamak 3	Zamak 5
Composition, Per Cent	Copper	0.10 max.	0.75-1.25
	Aluminum	3.5-4.3	3.5-4.3
	Magnesium	0.03-0.08	0.03-0.08
	Iron	0.100 max.	0.100 max.
	Lead	0.007 max.	0.007 max.
	Cadmium	0.005 max.	0.005 max.
	Tin	0.005 max.	0.005 max.
	Zinc (99.99% purity)	Balance	Balance
Properties	Tensile strength as cast, psi.	41,000	47,600
	Elongation in 2 inches, per cent	10	7
	Brinell hardness number	82	91
	Charpy impact value, ft. lbs.	43	48
	Shear strength, psi.	31,000	38,000
	Endurance limit, psi. (10^8 cycles)	6875	8175
	Compressive strength, psi.	60,000	87,000
	Weight, pounds per cubic inch	0.24	0.24
	Electrical conductivity (relative to annealed copper, per cent)	27	26
	Melting point, deg. F.	727.9	727.0

*Elements listed as max. constitute impurities.

Table 2. Composition of Aluminum Die-Casting Alloys, in Per Cent*

Alloy Series	Aluminum-Silicon				Aluminum-Silicon-Copper				Aluminum-Magnesium
Alcoa Number ...	13	43	A360	360	85	A380	380	384	218
Copper..........	0.60 max.	0.60 max.		0.60 max.	3.5-4.5		3.0-4.0	3.8	0.20 max.
Iron............	2.00 max.	2.00 max.		2.0 max.	2.3 max.		2.0 max.	......	1.80 max.
Silicon..........	11.0-13.0	4.5-6.0		9.0-10.0	4.5-5.5		7.5-9.5	12.0	0.30 max.
Manganese.......	0.30 max.	0.30 max.		0.30 max.	0.30 max.		0.50 max.	......	0.30 max.
Aluminum.......	Balance	Balance	See	Balance	Balance	See	Balance	Balance	Balance
Magnesium......	0.10 max.	0.10 max.	foot-	0.40-0.60	0.10 max.	foot-	0.10 max.	......	7.5-8.5
Zinc............	0.50 max.	0.50 max.	note	0.50 max.	1.00 max.	note	1.0 max.	......	0.10 max.
Tin.............	0.10 max.	......		0.10 max.	0.30 max.		......	......	0.10 max.
Nickel..........	0.50 max.	......		0.50 max.	0.50 max.		0.50 max.	......	0.10 max.
Others (total)....	0.20 max.	0.20 max.		0.20 max.	0.20 max.		0.50 max.	......	0.20 max.
Others (each)....	......	......		......	......		0.15 max.	......	......

*From data compiled by the Aluminum Co. of America. Elements listed as max. constitute impurities. Alloys A360 and A380 have the same nominal compositions as alloys 360 and 380, respectively, except that iron content and other impurities are held to closer limits.

Table 3. Properties of Aluminum Die-Casting Alloys*

Alloy ALCOA No.	13	43	A360	360	85	A380	380	384	218
Alloy ASTM No.	S5	S4	SG2	SG3	SC2	SC6	SC7	....	G2
Alloy SAE No.	305	304	....	....	307	306	308	....	....
Tensile strength, psi[1]	39,000	30,000	41,000	44,000	40,000	46,000	45,000	46,000	45,000
Tensile yield strength, psi[2]	21,000	16,000	23,000	27,000	24,000	25,000	26,000	27,000	27,000
Elongation in 2 inches, per cent	2.0	9.0	5.0	3.0	5.0	3.0	2.0	1.0	8.0
Shear strength, psi.	25,000	19,000	26,000	28,000	26,000	29,000	29,000	29,000	27,000
Endurance limit, psi[3]	19,000	17,000	18,000	19,000	22,000	19,000	20,000	21,000	23,000
Modulus of elasticity, psi.	10.3×10^6	10.3×10^6	10.3×10^6	10.3×10^6	10.3×10^6	10.3×10^6	10.3×10^6	10.3×10^6	10.3×10^6
Modulus of rigidity, psi.	3.85×10^6	3.85×10^6	3.85×10^6	3.85×10^6	3.85×10^6	3.85×10^6	3.85×10^6	3.85×10^6	3.85×10^6
Poisson's ratio	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Weight, pounds per cu. in.	0.096	0.096	0.095	0.095	0.099	0.098	0.098	0.098	0.093
Electrical conductivity (Relative to annealed copper, per cent)	31	37	30	28	28	25	23	23	24
Melting point, Deg. F.	1080	1170	1105	1105	1135	1100	1100	1080	1150

*Data obtained from Aluminum Co. of America. Mechanical properties data is for 68 deg. F.

[1] Tensile strength as cast—standard ASTM 1/4-inch round tensile specimen. [2] Yield strength at 0.2-per cent offset. [3] Based on 500,000,000 cycles of completely reversed stress on R. R. Moore type of machine and specimen.

Table 4. Composition and Properties of Copper Die-Casting Alloys

ASTM designation	Alloy A	Alloy B	Alloy C	......	......
Common or trade name	Yellow Brass	Doehler Brass No. 1	Doehler Brass No. 4	Doehler Brass No. 5	Tinicosil No. 10
Composition, per cent					
Copper	57.0 min.	63.0-67.0	80-83	83.0	46.6-47.1
Zinc	30.0 min.	Balance	Balance	Balance	Balance
Tin	1.50 max.	0.25 max.	0.25 max.	0.25 max.	......
Aluminum	0.25 max.	0.15 max.	0.15 max.	1.0	......
Lead	1.50 max.	0.25 max.	0.15 max.	0.25 max.	1.5
Manganese	0.25 max.	0.15 max.	0.15 max.	1.0	1.0
Nickel	......	......	......	......	10-10.5
Silicon	0.25 max.	0.75-1.25	3.75-4.25	5.0	......
Iron	0.25 max.	0.15 max.	0.15 max.	0.25 max.	1.0
Magnesium	......	......	0.01	......	......
Others (total)	0.50 max.	0.50 max.	0.25 max.	0.25 max.	......
Properties					
Tensile strength, psi.	65,000	75,000	95,000	110,000	90,000
Tensile yield strength, psi.	40,000	40,000	55,000	65,000	......
Elongation in 2 inches, per cent	15	25	8	5	20
Brinell hardness number	125	120	170	190	124
Weight, pounds per cu. in.	0.305	0.308	0.297	0.295	0.305
Melting point, deg. F.	1650	1575	1575	1564	1686

Table 5. Composition and Properties of Magnesium Die-Casting Alloys*

Designation	ASTM	AZ91A	AZ91B
	SAE	501	501A
	Dow Chemical Co.	R	RC
Composition, per cent	Aluminum	8.3-9.7	8.3-9.7
	Manganese	0.13 min.	0.10 min.
	Zinc	0.4-1.0	0.4-1.0
	Silicon	0.5 max.	0.5 max.
	Copper	0.10 max.	0.3 max.
	Nickel	0.01 max.	0.01 max.
	Others (total)	0.3 max.	0.3 max.
	Magnesium	Balance	Balance
Properties	Tensile strength, psi.	33,000	33,000
	Tensile yield strength, psi.[1]	22,000	22,000
	Elongation in 2 inches, per cent	3	3
	Shear strength, psi.	20,000	20,000
	Modulus of elasticity, psi.	6,500,000	6,500,000
	Modulus of rigidity, psi.	2,400,000	2,400,000
	Poisson's ratio	0.35	0.35
	Weight, pounds per cu. in.	0.066	0.066
	Electrical conductivity (Relative to annealed copper, per cent)	10.1	10.1
	Melting point, deg. F.	1120	1120

*Elements listed as max. constitute impurities. [1] Yield strength at 0.2% offset.

Table 6. Composition and Properties of Tin-Base and Lead-Base Die-Casting Alloys

ASTM designation	No. 1	No. 2	No. 3	No. 4	No. 5
Composition, per cent					
Tin	90-92	80-84	64-66	4-6	......
Antimony	4-5	12-14	14-16	14-16	9.25-10.75
Copper	4-5	4-6	1.5-2.5	0.50 max.	0.50 max.
Lead	0.35 max.	0.35 max.	17-19	79-81	89-91
Iron	0.08 max.	0.08 max.	0.08 max.	......	......
Arsenic	0.08 max.	0.08 max.	0.15 max.	0.15 max.	0.15 max.
Zinc	0.01 max.	0.01 max.	0.01 max.	0.01 max.	0.01 max.
Aluminum	0.01 max.	0.01 max.	0.01 max.	0.01 max.	0.01 max.
Properties					
Tensile strength, psi.	9000	10,000	7800	13,800	12,500
Elongation in 2 inches, per cent	2	1	1.25	10.5	2.0
Brinell hardness number	23-26	30	27.7	23.2	24.1
Weight, pounds per cu. in.	0.266	0.270	0.287	0.370	0.351
Melting point, deg. F.	400	400	450	493	514

a wide variety of applications. Light weight, good conductivity, and freedom from intergranular corrosion make these alloys particularly useful in the electrical industry. These alloys may be finished in a wide variety of attractive colors which have considerable surface endurance. Aluminum die-castings are used extensively for parts of vacuum cleaners, household appliances, cameras, motors, instrument housings and for a variety of other articles.

The disadvantage of aluminum die-casting alloys lies primarily in the higher casting temperatures required, higher die costs due to erosion and heat checking of the dies, and slower production rates.

The impurity tolerances for aluminum alloys are relatively wide except for the amount of iron which is permissible. The presence of more than 2 1/2 per cent iron makes aluminum die-castings brittle, although the presence of small amounts of iron increases the strength of the alloy. Silicon is the most useful alloying element for aluminum. It effectively lowers the melting temperature and increases the fluidity of the metal. The aluminum-silicon alloys shown in Table 2 are primarily used for large castings or those of complex shape. Although their tensile and yield strengths are not as high, nominally, as for other aluminum alloys, their effective strength in castings of difficult shape is greater because of the greater soundness attained in these castings. The resistance to corrosion of aluminum-silicon alloys, particularly salt water corrosion, is greater than that of aluminum-silicon-copper alloys and they are preferred for such applications although they are more difficult to machine.

The use of copper as an alloying element in the aluminum-silicon-copper series has the same general effect as silicon. It increases the strength of the metal, lowers the melting point, and increases the fluidity although to a lesser extent than silicon. Alloys containing copper have better machinability than those containing silicon alone.

The aluminum-magnesium type of alloy displays the best combination of high strength and ductility of all aluminum die-casting alloys. It has the highest resistance to corrosion and is adaptable to protective chemical or anodic coatings. These alloys are easy to machine although they are comparatively difficult to cast, and casting of intricate shapes is impracticable.

Copper-Base Die-Casting Alloys. — Copper - base alloys (Table 4) possess superior properties as regards strength, impact value, and elongation, and they are not affected by many chemicals or atmospheric conditions. The impact value of brass die-castings is greater than that of sand castings of the same alloy and equal to that of forgings in some cases.

The Doehler Die Casting Co. produces a copper-silicon-zinc alloy known as "Brastil" (ASTM No. C) which has a strength equivalent to that of medium carbon steel. It can be accurately cast into intricate shapes. Brastil has been used for cams, automobile-door strikers, tie-rod brackets, etc.

Another copper-silicon-zinc alloy known as "Doler-Brass" (ASTM No. B) is intended for general use in brass die-casting when the superior strength of Brastil or the appearance of white nickel brass is not required.

Alloys A, B and C are the most commonly used although other copper-base alloys have found application, notably the aluminum-bronzes and magnesium-bronzes. The casting temperatures of the latter alloys, however, are too high for more general application since die life is considerably shortened. Other alloys such as Tinicosil are sometimes used in place of German silver and similar alloys, but these also have the disadvantages common to alloys of high melting point. Copper alloys are in general the most difficult of all alloys to die-cast, require the largest sizes of die-casting machines, the highest injection pressures, and are, comparatively speaking, the most expensive.

Magnesium-Base Die-Casting Alloys.–Magnesium-base alloys (Table 5) are about two-thirds as heavy as aluminum and approximately one-fifth as heavy as brass. Magnesium-base alloys ASTM Nos. AZ91A and AZ91B are commonly used for die-casting purposes. Typical applications of these alloys are small tool handles and parts for airplanes, typewriters, and adding machines.

In addition to being light in weight, magnesium castings are easy to machine, have high dimensional stability and are non-magnetic and non-sparking.

Lead-Base Alloys.—Lead-base alloys find wide application because of the resistance they offer to many chemicals. They are also extensively used for bearing purposes, toys, and novelties. They are naturally not adapted for stressed machine parts, because of their low strength. Neither are they suitable for parts that are to handle food products, because of the poisonous lead compounds likely to be formed.

The hardness of lead-base alloys can be increased by adding to the antimony content. Tin improves the strength and the fluidity. Lead alloys are shown in Table 6.

Tin-Base Alloys.—Tin lends itself well to die-casting because of its low melting point; but as its cost is high, the cheaper low-melting metals are generally selected, unless resistance to certain liquids is essential. Thus, tin-base alloys are used for die-casting syrup cups, soda-fountain appliances, milking-machine parts, and other articles that must be immune to the action of acids from foods and food products or to alkalies; the copper and lead content, however, must not be enough to form poisonous compounds with the liquids handled. Tin alloys have only a small shrinkage in cooling, and so they are particularly desirable when accuracy is essential in castings. Tin-base alloys are not adapted for highly stressed machine parts, but they do possess valuable bearing properties. Some of the tin alloys used for die-casting are shown in Table 6.

Die-Casting Dies and Their Operation

The die in which the casting is formed is, of course, a very important element in the die-casting process. Since die-castings are extensively used in connection with the manufacture of an endless variety of mechanisms requiring accurate interchangeable parts in quantity, there is a corresponding variety of dies differing more or less in their design or arrangement. Each form of casting presents a different problem in die design and diemaking. Repeated experiences in the use of dies have resulted in great developments in their design; improved tools have also assisted greatly in forming die-cavities of the required shape and accuracy in the steel die-blocks. While the ideal die is simplified as far as possible, it is common practice to employ dies having as many as twenty-five or thirty cores for a single casting.

General Requirements of Die-Casting Dies.— Before considering specific types or designs of dies, the general requirements will be mentioned. These are as follows: (1) The die must form castings of the required shape, size and accuracy, and without interfering with the free removal or ejection of the casting; (2) it must permit the free flow of the molten metal into every part of the cavity when the metal is forced through the sprue and gate, or gates, under a pressure which may range from a few hundred up to thousands of pounds per square inch; (3) the die must be arranged to form holes or interior openings, if required, by the use of cores; (4) provision is necessary for withdrawing the cores either manually or by a core-operating mechanism; (5) the die must be formed of two or more sections to permit opening it and removing the casting, the dividing or parting line being in whatever plane (or planes) is most conducive to ejecting the casting; (6) provision must be made for ejecting the casting after the two die sections have been opened.

To design and construct dies meeting these and allied requirements is the work of a specialist, particularly if the die-casting is a complicated form. This subject cannot be dealt with adequately in an abstract manner. However, considerable information of practical value can be acquired by studying the design of dies which have proved successful in actual practice. For this reason detailed descriptions of dies, accompanied by photographs and drawings illustrating their general arrangement, are an important feature of this book. In view of the fact that die-casting is now so generally applied to such a large variety of work, it is, of course, impracticable to show designs of dies representing every form or type of casting likely to be produced by this process. An attempt has been made, however, to include dies designed for certain general types of castings representing distinct die-casting problems. By studying these designs, the same general principles in many cases, at least, can be applied in the construction of dies for numerous other forms of castings.

Simple Type of Die-Casting Die Illustrating Operating Principles.— The operating principles of die-casting dies can be easily explained by means of a simple example. In Fig. 1 is shown a set of dies for producing a circular dish-shaped casting of the outline indicated at *X*. The dies consist of a stationary member *A* and a movable member *B* which is closed against the face of the stationary member as shown for each operation. In this particular set of dies the die-cavity or mold into which the molten metal is "shot" to

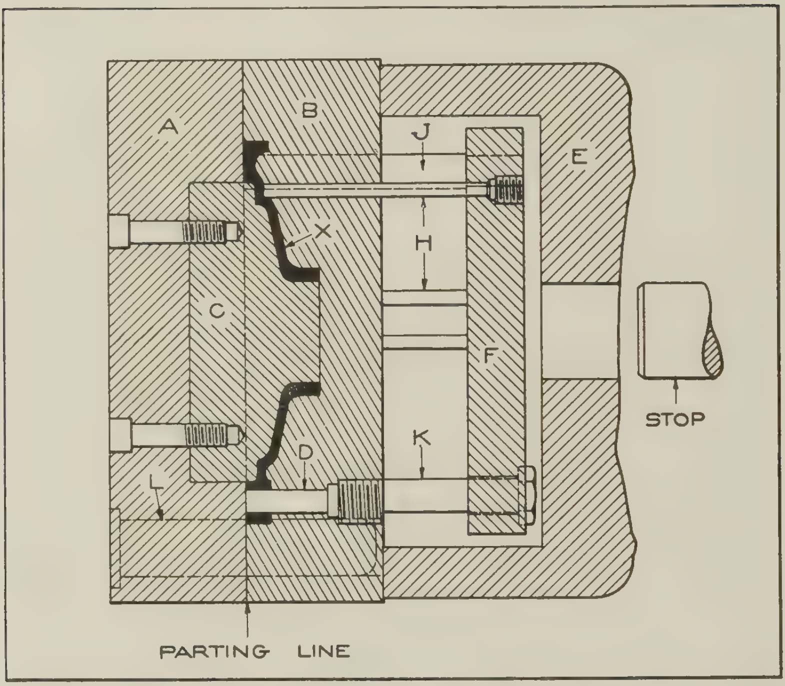


Fig. 1. Simple Type of Die-casting Die Illustrating Typical Features and Principle of Operation

form the casting is contained entirely in the movable die *B*. The outside surfaces of the casting are completely formed by the cavity, while the inside of the die-casting is shaped by a fixed core *C* attached to the stationary die. Holes are cored through the flange which extends around the casting by means of pins *D* (only one of which is shown) which are held in the movable die by means of headless set-screws.

How the Casting is Ejected from the Die.—Upon the completion of each operation, the movable die and the housing *E* to which it is attached are withdrawn from the stationary die to enable ejection of the casting. This may be effected automatically or manually, depending on the type of machine in which the dies are being used. In the example illustrated ejection occurs when a stop-bar mounted on the machine comes into contact with plate *F;* the plate is thus held stationary while the other parts of the movable die complete the opening stroke. Attached to plate *F* are a number of long slender pins *H* which extend through die-block *B* to the die-cavity. Therefore, as block *B* completes its movement to the right after plate *F* has been stopped, pins *H* push the casting from the cavity. When the mov able die is returned against the stationary die, four pins *J* mounted near the corners of plate *F* project from the face of the movable die and contact against the stationary die. They return plate *F* and pins *H* into the positions shown as the movable die completes its closing stroke. The dies are then ready for the next operation.

Plate *F* is attached to die-block *B* by means of two studs *K*, only one of which is shown. Two guide pins *L* mounted on the stationary die diametrically opposite each other enter holes in the movable die to insure correct registry of the dies when they are closed.

Many variations of the elementary principles here explained are found in die-casting dies. Different methods of ejecting the casting are employed and various types of fixed and sliding cores are used. The die-cavity may be entirely in the movable die, as in the example shown, completely in the stationary die or partly in both.

Parting Line Between the Fixed and Movable Dies.—Since each die consists primarily of two parts, stationary and moving, there will always be a parting line on the casting. It is the practice to locate this parting line at the point that will permit easiest ejection of the casting from the die, at the same time keeping in mind the appearance of the joint on the finished part. Whenever it is practicable to do so, the parting line is located on an edge of the casting.

The parting line may be in one plane, as in the example illustrated, or it may follow an uneven path. Dies are made with one cavity and with a multiple number of cavities. The following pages will describe many die-casting dies which have been selected to bring out the design variations that are possible.

Vents for Escape of Air as Metal Enters Die.—It is essential to vent dies, whenever necessary, in such a manner that the air can escape quickly with the onrush of the molten metal. For this purpose, wide, shallow grooves or vents may be provided in the faces of the die halves. These grooves allow the air to escape at the proper speed and cause the metal to "freeze" as it attempts to enter the shallow passages, which effectively stops the flow of metal. The air vents are made from 0.003 to 0.005 inch deep and from 1 to 1 1/2 inches wide. They are usually placed on the face of the die member which contains the cavity.

Proper venting of dies requires considerable experience. Generally speaking, when moving cores are provided, the slight amount of clearance around the cores allows sufficient venting. Sometimes enough air can escape between the faces of the two die halves, but, of course, there must not be sufficient space to permit the molten metal to flow out. Frequently dies are made and tried out before the matter of venting is considered at all.

Die for Housing of Portable Electric Saw.—A saw housing (Fig. 2) is produced with the die illustrated in Fig. 3. It will be seen that the stationary member of this die is equipped with a large cylindrical core *A*, at the center of which there is a small core that must be withdrawn prior to the opening of the die at the end of each operation. The moving die member is equipped with a long, slender core *B*, which produces a hole running from the handle of the housing to the motor compartment. This core is pulled back after the die has opened, so as to release the casting. Several shallow vents may be seen on the face of the stationary member. The parting line runs along the center of the work. Both the front and rear housings are given a high finish after the gate and flash have been ground off.

Die for Heat-Regulator Housing.—Fig. 4 shows a die of simple design employed in casting a cover for a heat-regulator housing. Both the movable and stationary members have a core which is pulled from one side, one core from the right and the other from the left. Cores for various other openings and holes are fastened to both the stationary and moving members. Air vents can be clearly seen on the face of the stationary member, which is shown at the right in the illustration. The parting line on this casting runs along one edge.

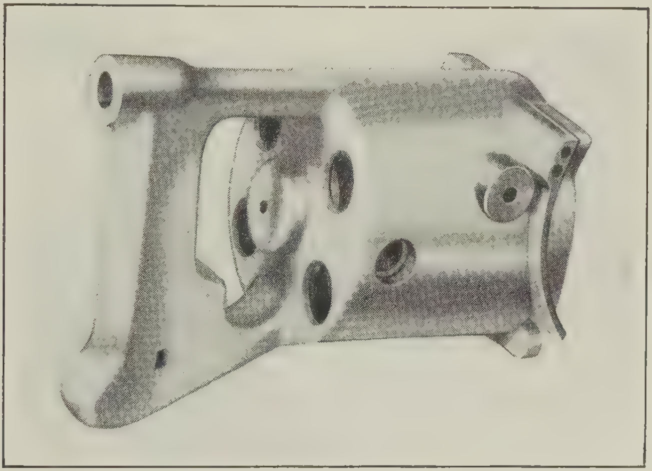


Fig. 2. Typical Motor Housing for Portable Electric Tools, Produced in Die Shown in Fig. 3

Dies for Moving Picture Machine Housing.—The parting edge of the moving picture machine casting shown in Fig. 5 extends about from points *A* on the circular portion, backward until the main part of the casting is reached where it runs out to edge *B* and extends around this edge. Fig. 6 shows the die used for the production of this part. The die is typical of many that produce a trade emblem on the casting with the outline and reading matter clear and distinct.

The moving member of this die has a large stationary

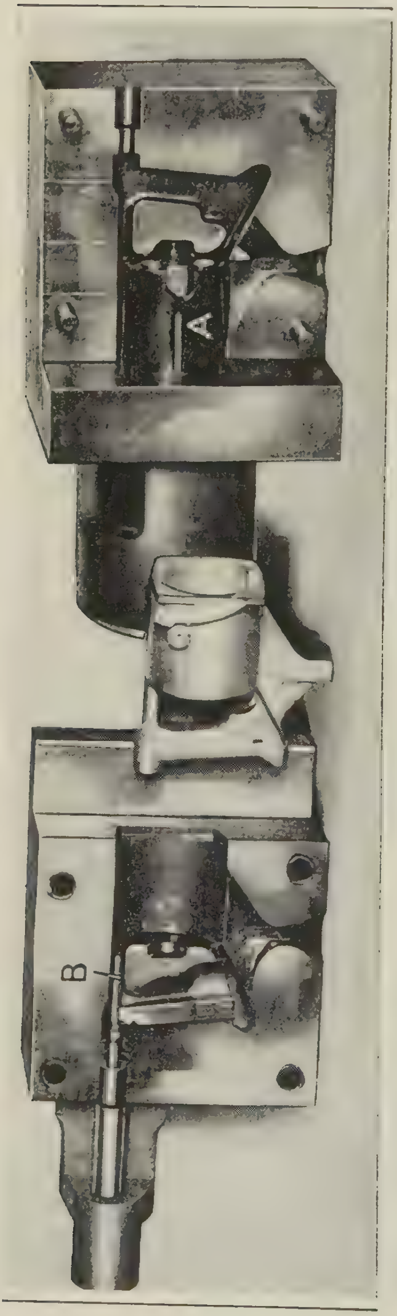


Fig. 3. Construction of Die Used in Casting a Rear Portable Electric Saw Housing (Shown in Fig. 2) which Requires the Pulling of a Slender Core from the Handle

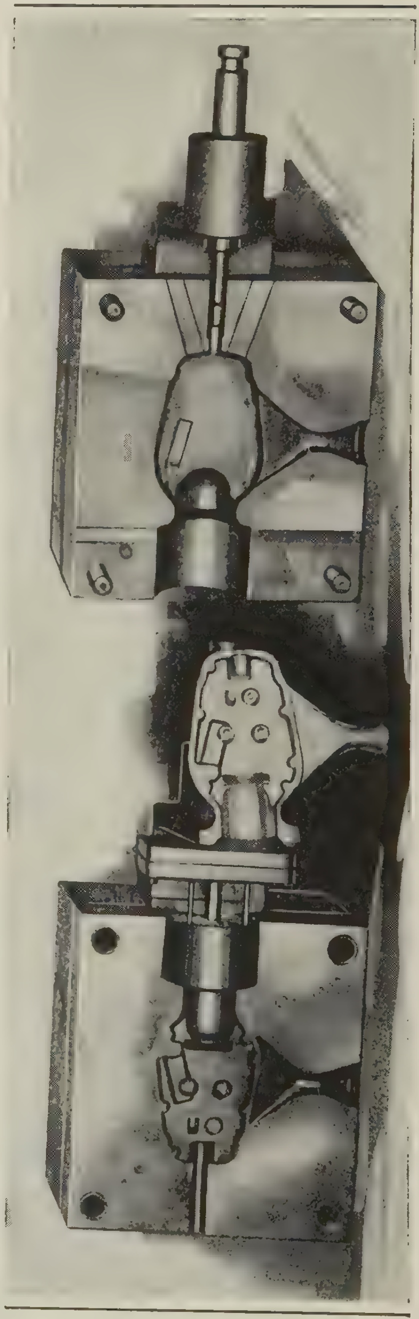


Fig. 4. Simple Die Employed for Producing a Thin Part Having a Circular Flange at One End

core or plug *A* and a vertically sliding core *B*. When the die closes, the hole in block *C*, attached to the upper end of the core, slides over the tapered pin held in block *D* of the stationary die, thus accurately positioning core *B* for the casting operation. At the end of the operation, block *D* is raised before the die is opened, core *B* thus being lifted also. When block *C* then slides off the tapered pin on block *D* as the die opens, core *B* again drops into place. Cores are also pulled sidewise from the stationary die by means of rods *E* and *F*.

This casting is made to adhere to the moving die member, although the tendency is for it to remain on the stationary member. The latter is provided with eighteen ejector-pins. This part is an aluminum casting measuring approximately 8 by 5 by 2 1/2 inches over-all. It is later given a crackle-lacquer finish in various colors.

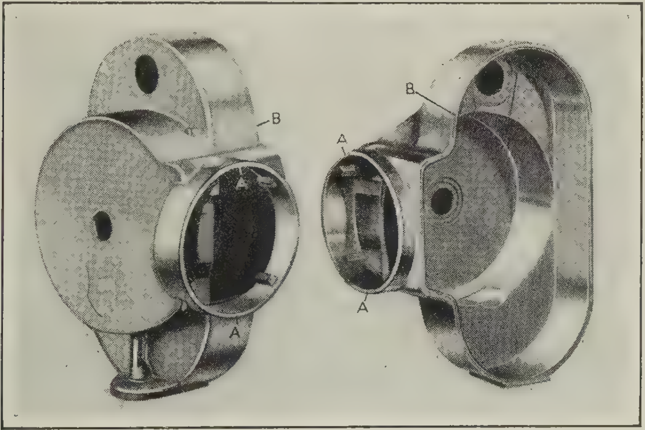


Fig. 6. Two Views of a Die-cast Moving Picture Machine Part

Die Equipped with Core-Pulling Mechanism.—The die, Fig. 7, has in addition to the stationary member *A* and the moving member *B*, core mechanisms arranged on two sides of the die, as indicated at *C* and *D*. These mechanisms automatically place various sliding cores in position ready for

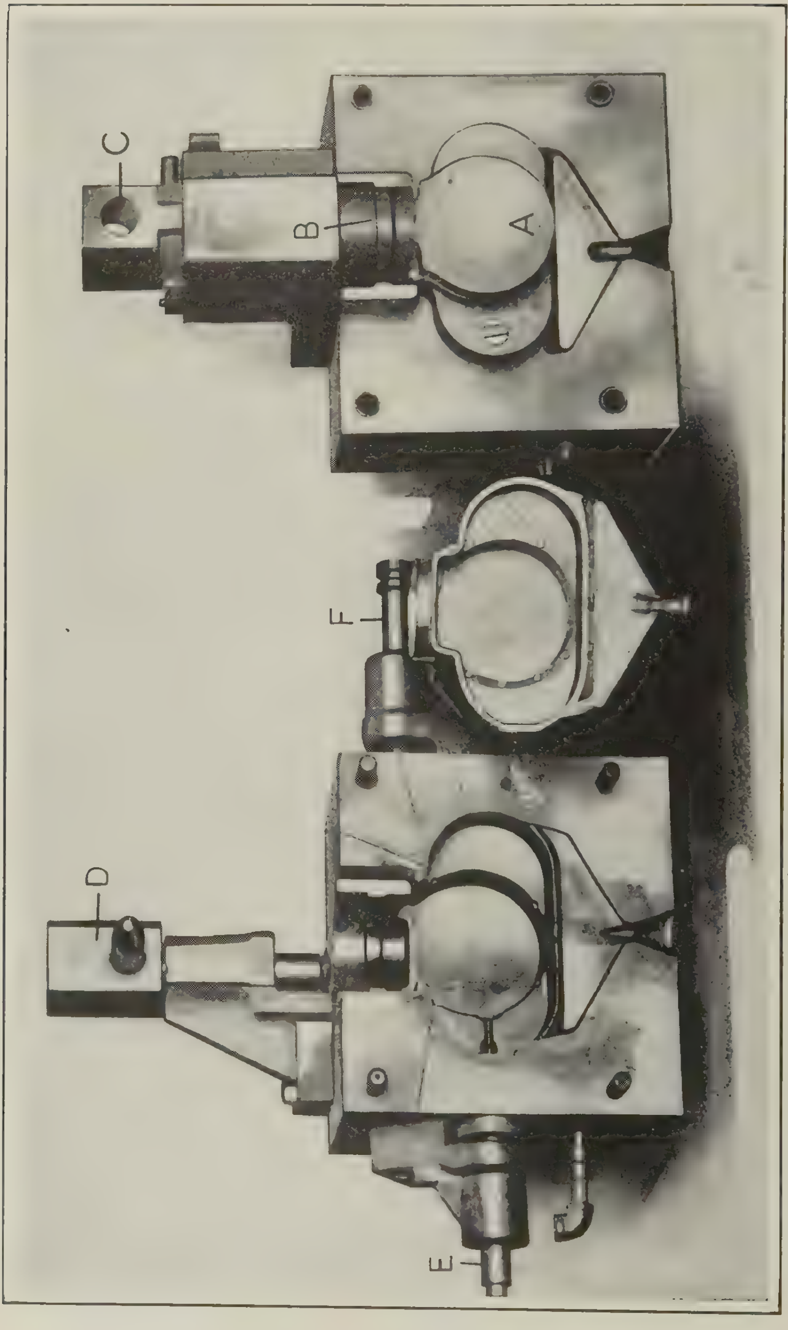


Fig. 6. Die Design Embodying a Heavy Core on the Movable Member which is Operated by a Lifting Device on the Stationary Member

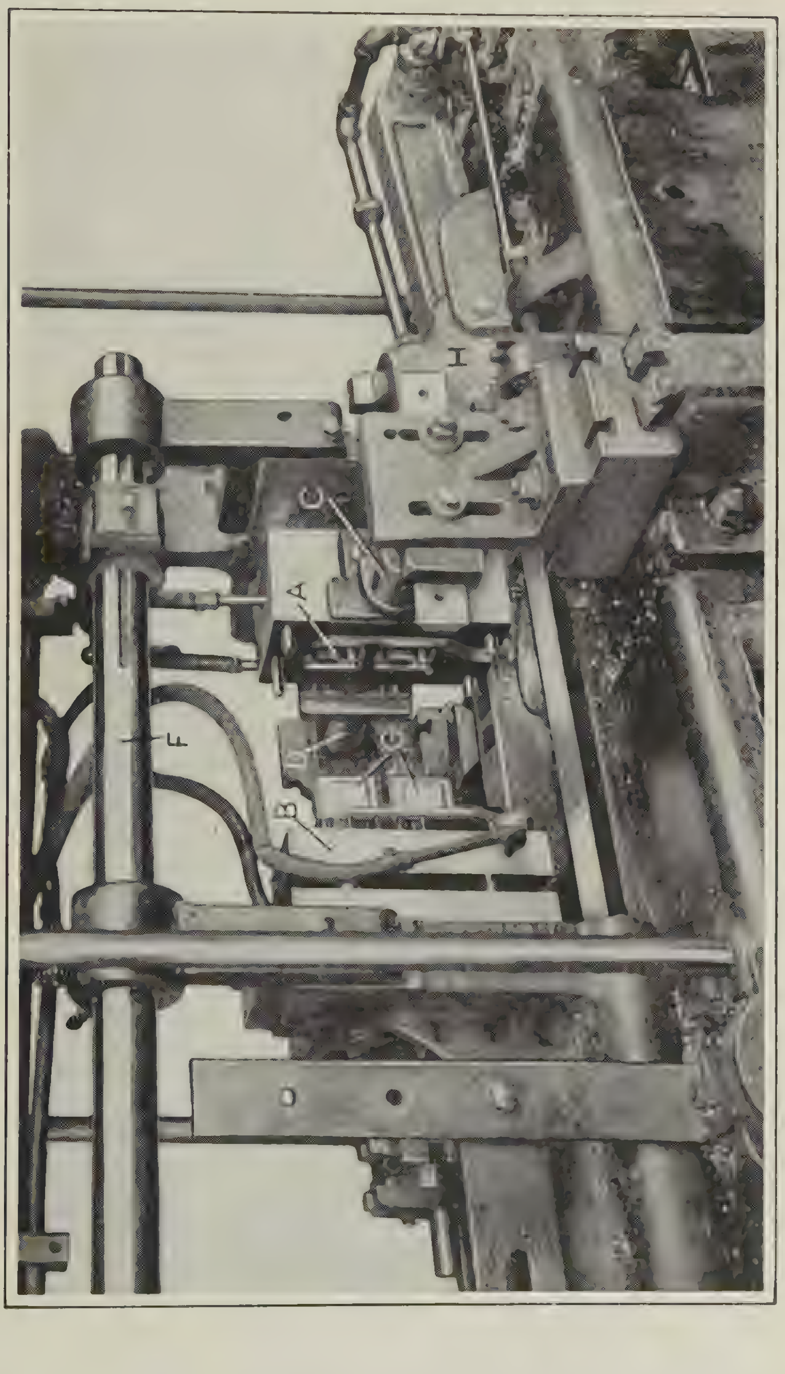


Fig. 7. Die-casting Machine Equipped with a Die Having Cores Pulled from Both Sides

the casting operation, after the moving die member has advanced into position against the face of the stationary die. The mechanisms withdraw the cores after the casting has been made and before the moving die member opens up. The core-pulling mechanisms are operated through the swiveling of shafts which extend along the front and rear of the machine. These shafts are connected by means of cranks to the slides on which the cores are mounted. The cores may be operated vertically through motion imparted by shaft *F*.

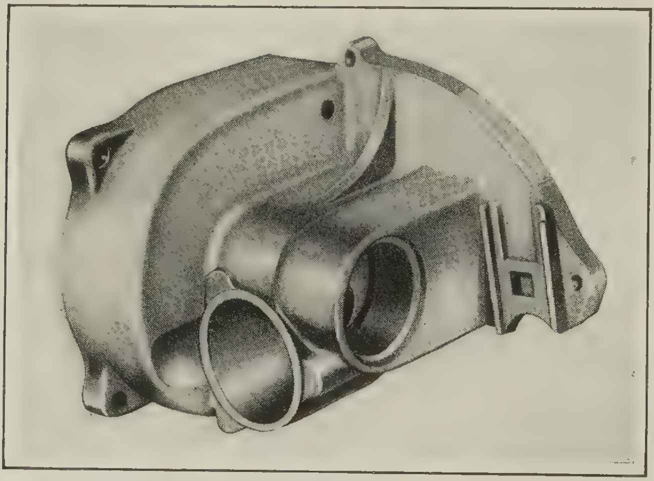


Fig. 8. Front Housing for a Portable Electric Saw which is Produced in the Die Shown in Fig. 9

Two small castings *G* are produced simultaneously with this die equipment. The stationary member of the die is mounted, according to the standard practice, on a plate attached solidly to the machine bed, while the movable member is secured to a ram that slides on dovetail ways of the bed, positioned on each side of the reservoir which contains the molten metal. The metal is forced into the gate of the die after the die has been closed, and the gooseneck *H* is swiveled to bring the nozzle at its forward end against the die gate.

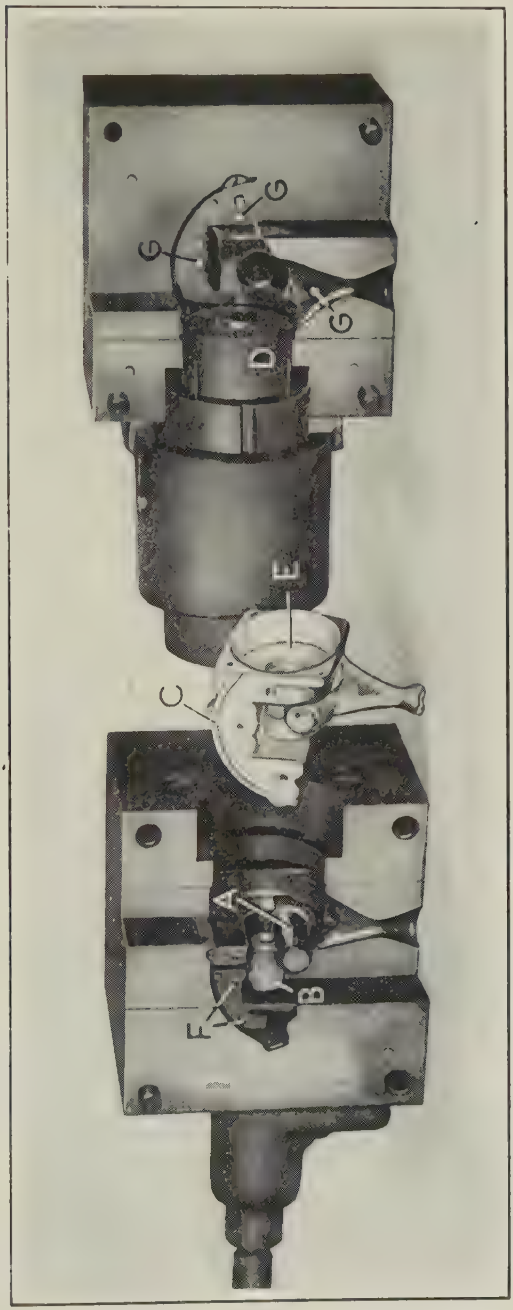


Fig. 9. Die Having Two Interlocking Cores which Produce Shaft Bores at Right Angles to Each Other

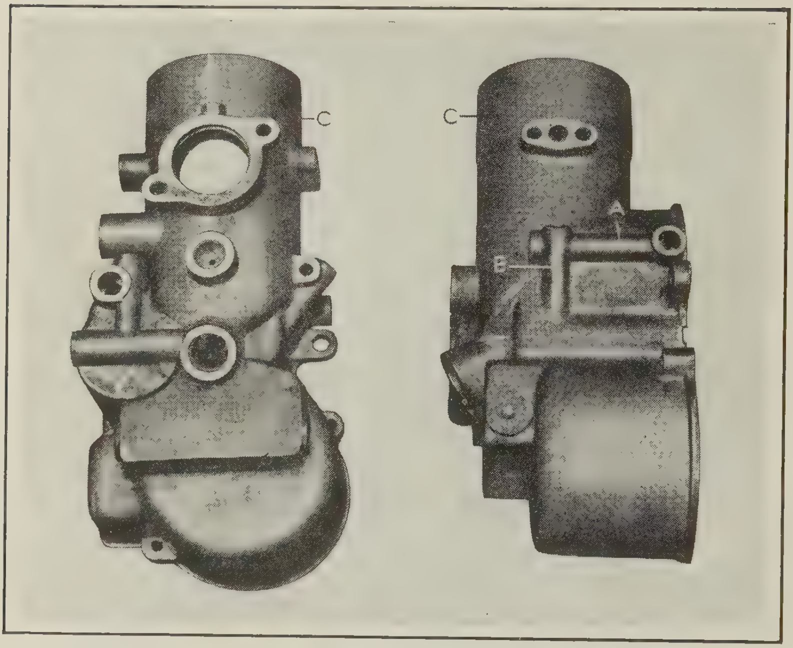


Fig. 10. Die-casting Produced in Movable Die that has Cores Sliding in Five Directions and that Opens Sidewise

Die Having Two Interlocking Cores Located at Right Angles.—A front housing for a portable electric saw is shown in Fig. 8. Owing to the fact that there are shaft-holes at right angles to each other in the front housing, a die design of more than passing interest had to be employed. From Fig. 9, which shows the die, it will be seen that one shaft bore is produced by core *A*, which is attached to the stationary die member, while the bore at right angles to the other one is produced by means of core *B*. Core *B* is advanced to interlock in a groove of core *A* before the operation is performed and is withdrawn from it immediately at the end of the operation, as the die could not otherwise be opened.

Instead of the contact faces of these die members being flat, they are of a stepped construction, as necessitated by the casting design. The parting line occurs along edge *C* of the casting. It will be seen that on the moving member there is a large-diameter core *D* which produces the circular hollow *E* in the work. Core *D* is pulled sidewise to permit ejection of the casting. Ejecting-pins are located at various points on the stationary and moving die members, as indicated at *F* and *G*, respectively.

Carburetor Die with Cores which Move in Five Directions.— Fig. 10 shows a carburetor casting of a design requiring the use of a movable die that opens sidewise after it has withdrawn from the stationary die. In addition, cores sliding in five directions are required. The movable die is illustrated in Figs. 11 and 12, Fig. 11 showing the various

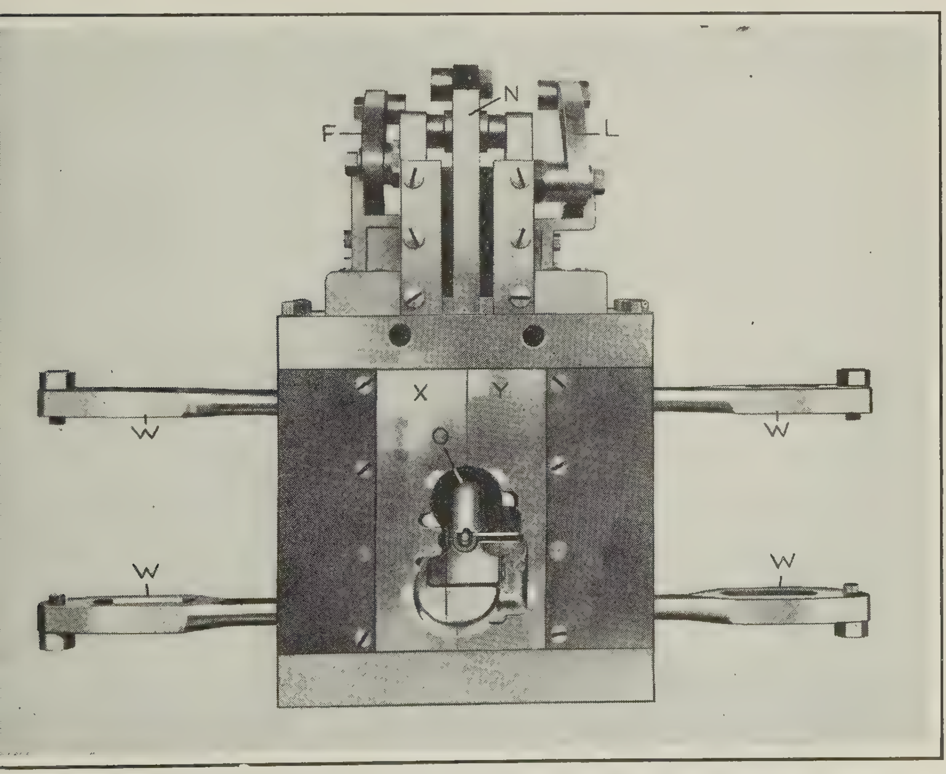


Fig. 11. Movable Die with All Moving Cores and the Two Cavity Slides in the Casting Position

sliding members in the casting position, and Fig. 12, in the positions they occupy when the movable die is withdrawn from the stationary member. Fig. 13 shows the stationary member of the die. The casting produced is approximately 6 5/8 by 3 1/4 by 2 7/8 inches in size, and weighs about 1.6 pounds. The production averages 70 castings per hour.

The sliding cores in the movable die are operated by two combination bars on top of the machine and two on each side, six bars being required in all. The machine is a Madison-Kipp automatic. The combination bars are fitted with cam-blocks. As rollers attached to the different operating levers of the movable die pass along the cam-blocks

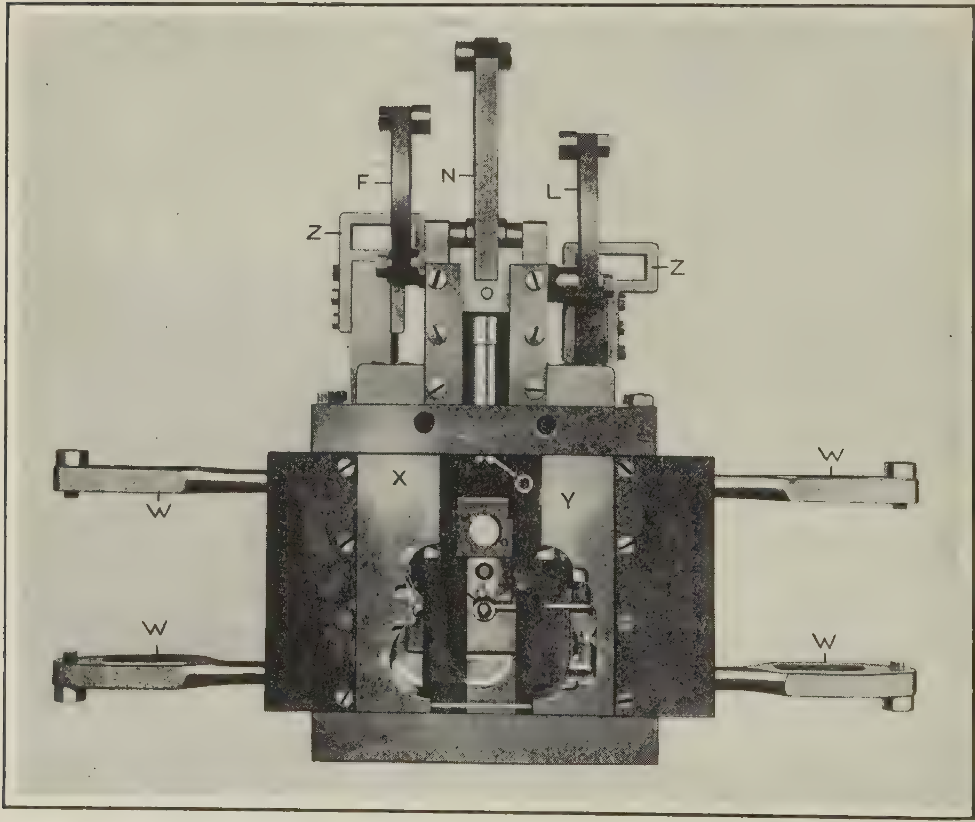


Fig. 12. Movable Die with All Moving Cores Withdrawn and with the Cavity Slides Open Sidewise

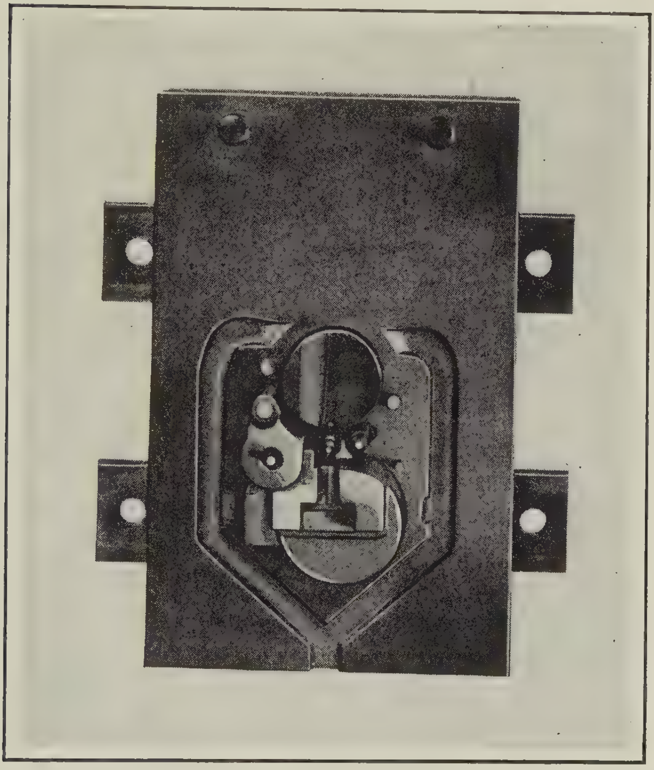


Fig. 13. The Stationary Die used with the Movable Die Shown in Figs. 11 and 12

of the combination bars when the die carriage of the machine moves back and forth to open or close the dies, the different sliding parts are moved into place or withdrawn as required.

Cores are Withdrawn before Die Opens Sidewise.—Assuming that the movable die is closed against the stationary die, with all sliding parts positioned as shown in Fig. 11, when the movable die starts to withdraw, bellcrank lever *F*, Fig. 14, is swiveled to raise slide *G*. This slide has a cam slot *a* in it which is engaged by a small roller attached to the holder in which core *H* is mounted. Consequently,

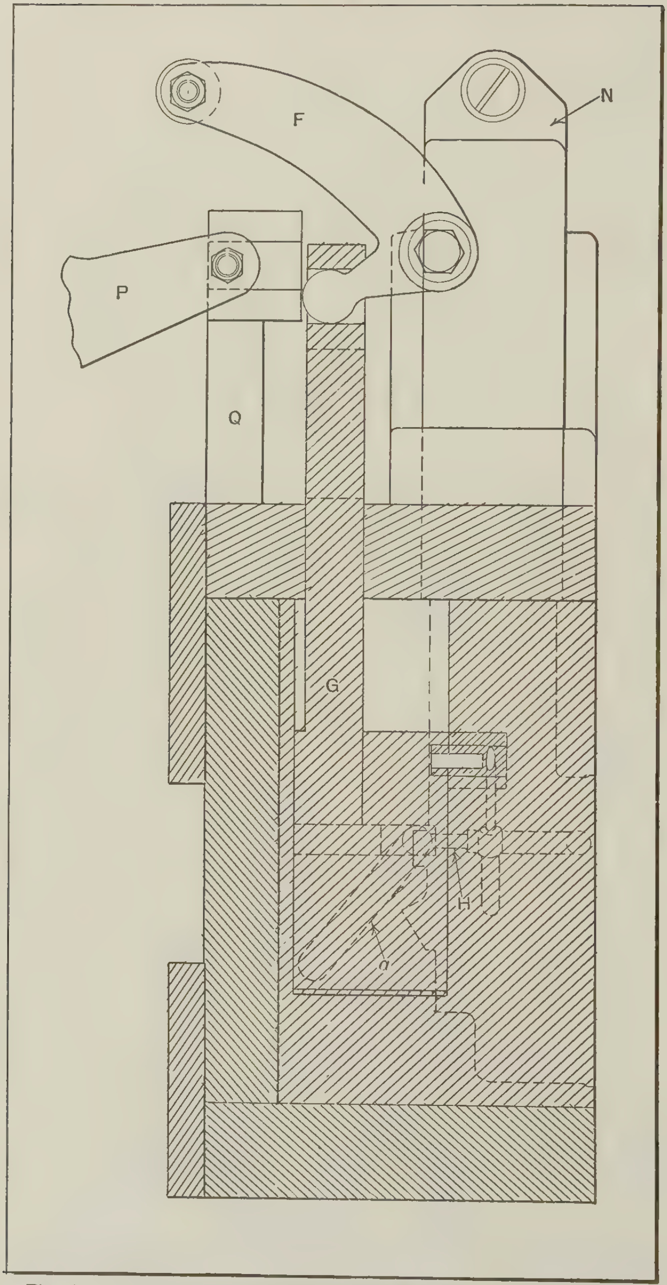


Fig. 14. Sectional View of Movable Die, Showing Arrangement Used for Moving a Core Horizontally

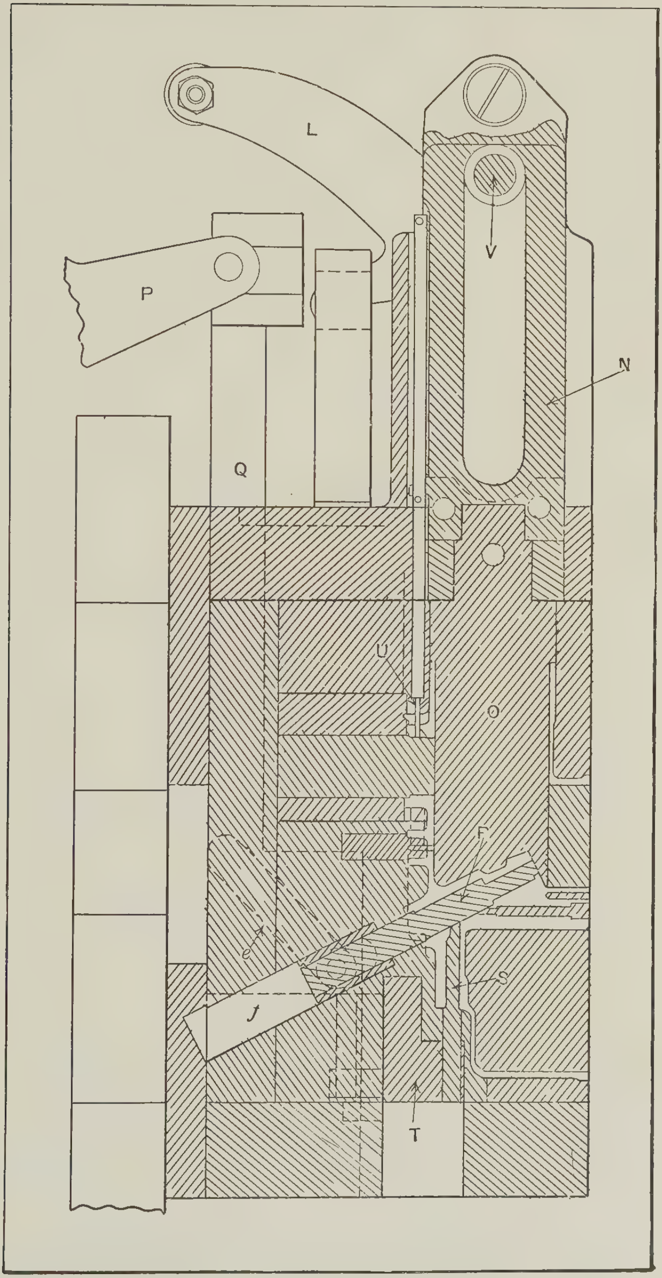


Fig. 15. Section Showing Means Employed for Moving Three Cores Vertically and One Core at an Angle

as slide *G* is raised, core *H* is withdrawn horizontally. This core produces the hole in boss *A*, Fig. 10. The same mechanism is used to withdraw the core that forms the hole in boss *B*. This core is indicated at *J*, Fig. 16, and its movement is effected through a cam slot *b* which is machined in the face of slide *G* at right angles to the face on which cam slot *a* is provided. A roller attached to holder *K* of core *J* engages cam slot *b*, and so as slide *G* is raised, the holder is withdrawn along slot *d* of the die body at an angle of about 30 degrees with the vertical.

While the mechanism just described is in operation, lever *L* on the opposite side of the die is swiveled by the cams of the second combination bar on top of the machine, thus raising the slide to which the slender core *M* is attached. This core is given a direct vertical movement of approximately 1 1/4 inches.

Movement of Large Core.—Rod *N* is also lifted simultaneously to impart a vertical movement to the large round core *O*, Figs. 15, 11, and 12, which extends to the middle of the die-cavity for forming the hole in the tubular end *C*, Fig. 10, of the casting. Core *O* has a movement of about 4 1/2 inches. Near the end of this movement a slight vertical movement is also imparted to the slender core *U*, Fig. 15, attached to slide *N*. This core produces a hole about 1/16 inch in diameter in a boss on the casting. Roller *V*, which is held in two bearings of the die proper, offers a sidewise support to slide *N* in its vertical movements.

Lever *P*, Fig. 15, is attached to the movable die carriage and is operated by a roller at its upper end which engages cam-blocks on one of the combination bars on top of the machine. Thus, cam-blocks are used on both sides of the two top combination bars. When lever *P* is swiveled as the movable die carriage is withdrawn, it moves slide *Q* down. On one side of this slide there is a cam slot *e* which is engaged by a roller mounted on the sleeve of core *R*. Therefore, as slide *Q* moves down, this core and its sleeve are

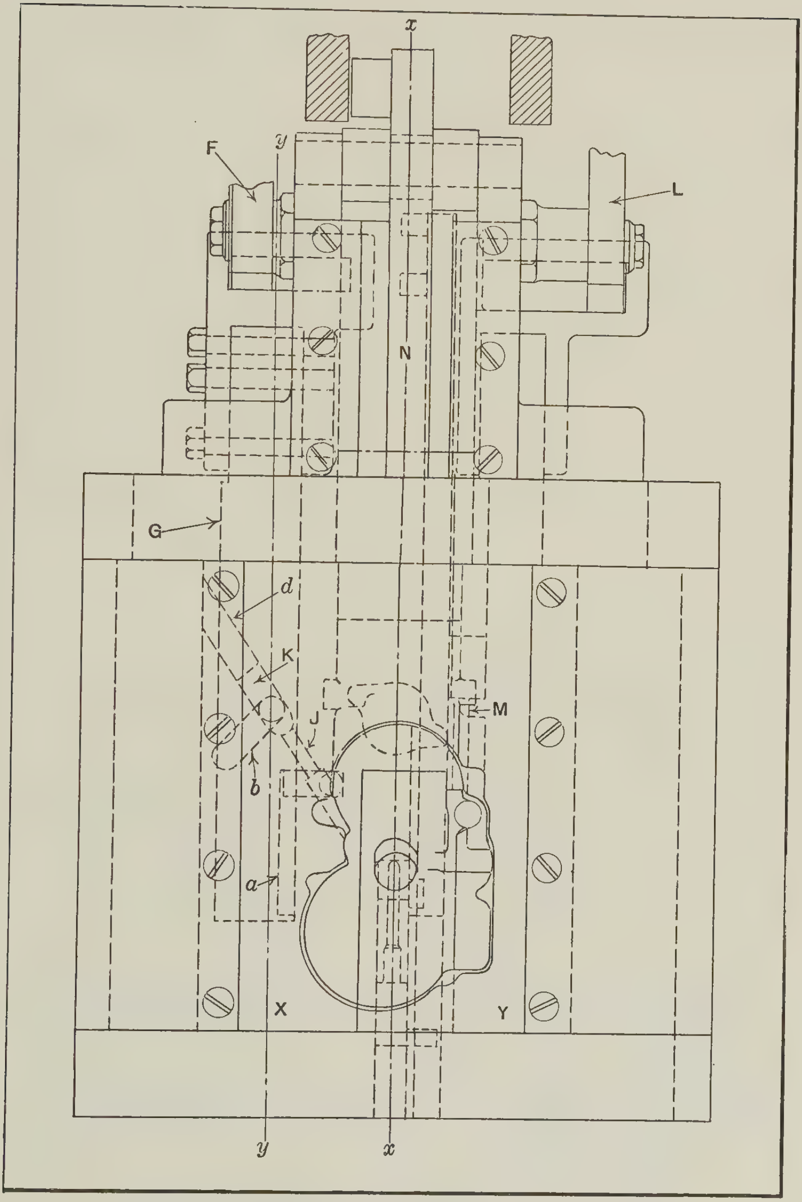


Fig. 16. Mechanism Employed for Moving a Core at an Angle of 30 Degrees with the Vertical

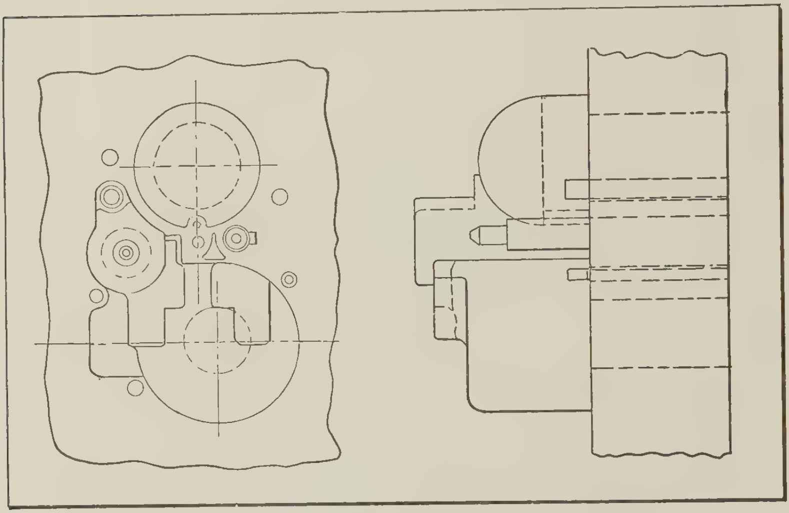


Fig. 17. Fixed Cores on Face of Stationary Die (Fig. 13)

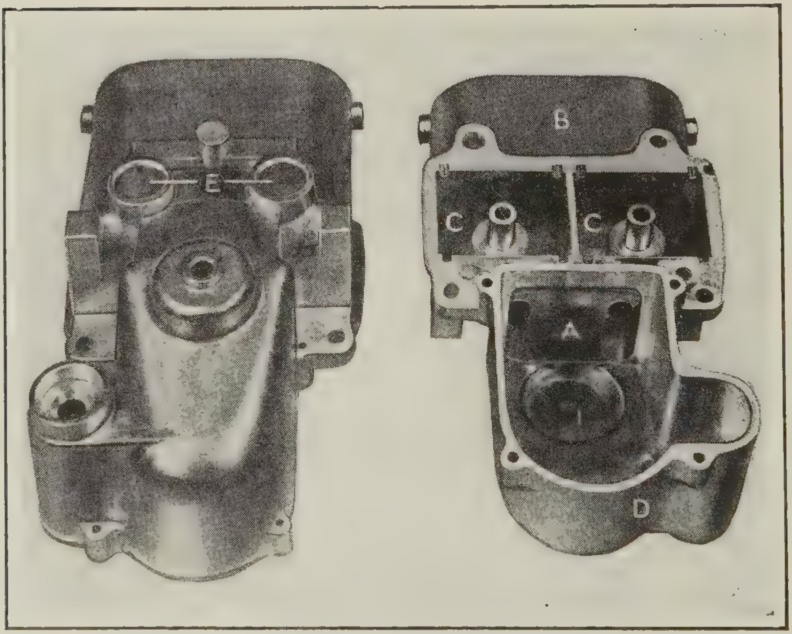


Fig. 18. Carburetor Body Produced in a Die Equipped with a Core that Must be Moved at an Angle for Producing Pocket A and Recesses Leading from it

withdrawn along hole *f*. Simultaneously, core *S*, with holder *T*, is lowered 1 1/2 inches by lugs on slide *Q*.

How the Dies Open Sidewise.—After the movable die carriage has been withdrawn sufficiently to permit the operation of all sliding cores in the manner just described, the rollers on the outer ends of rods *W*, Figs. 11 and 12, engage the cam-blocks of the side combination bars in such a way as to pull the slides on which die-blocks *X* and *Y* are mounted away from each other. These rods are not shown in Fig. 16; however, they are fastened directly to the die slides and pull these members straight out.

Levers *F* and *L* operate in the slots of brackets *Z*, which are clearly shown in Fig. 12. These slots provide clearance for the levers during the outward movement of die-cavity blocks *X* and *Y*, brackets *Z* and the slides on which they are mounted traveling with these blocks.

From Figs. 17 and 13 it will be observed that the stationary die consists principally of a series of fixed cores which project from the face of the die-plate. The sprue and the passages through which the molten metal flows to the die-cavity in the movable die under a pressure of 350 pounds per square inch are cut entirely in the stationary die. Pilot pins on the stationary die engage holes in the movable die to register the two die members accurately in the casting position.

Dies for Carburetor Body Requiring Core at 45-Degree Angle.—In designing dies for producing the carburetor body shown in Fig. 18, provision had to be made for pulling a core at an angle of approximately 45 degrees, in order to produce pocket *A* and the two recesses and holes that lead from it into the upper portion of the casting. Another core moving vertically had to be provided for forming the chamber within end *B*, this end being open. Various stationary cores were necessary on both the movable and the stationary dies, all of which were on horizontal axes. This

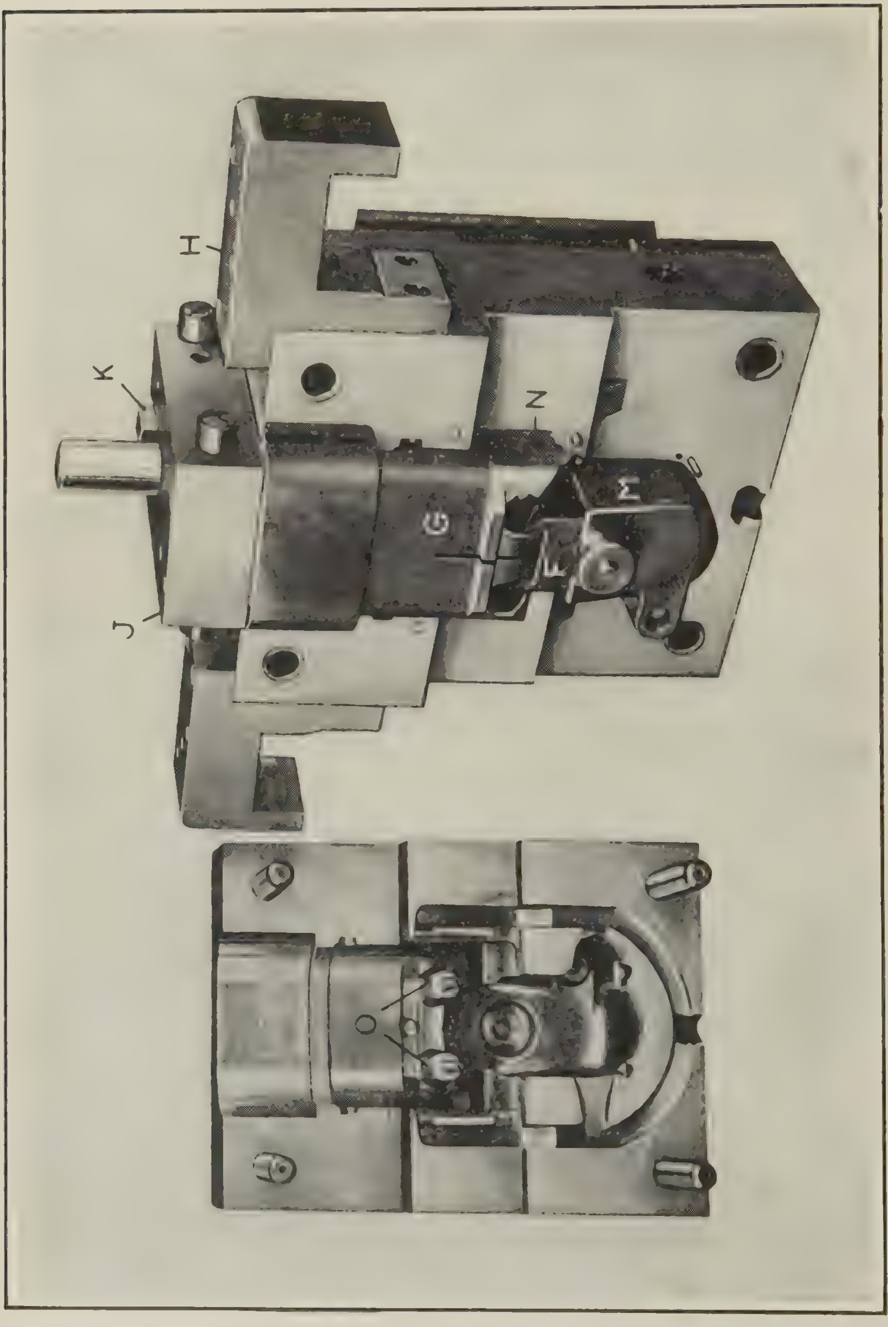


Fig. 19. Die Members Used in Producing the Carburetor Body, the Movable Die at the Right Being Shown with the Moving Cores in Their Casting Positions

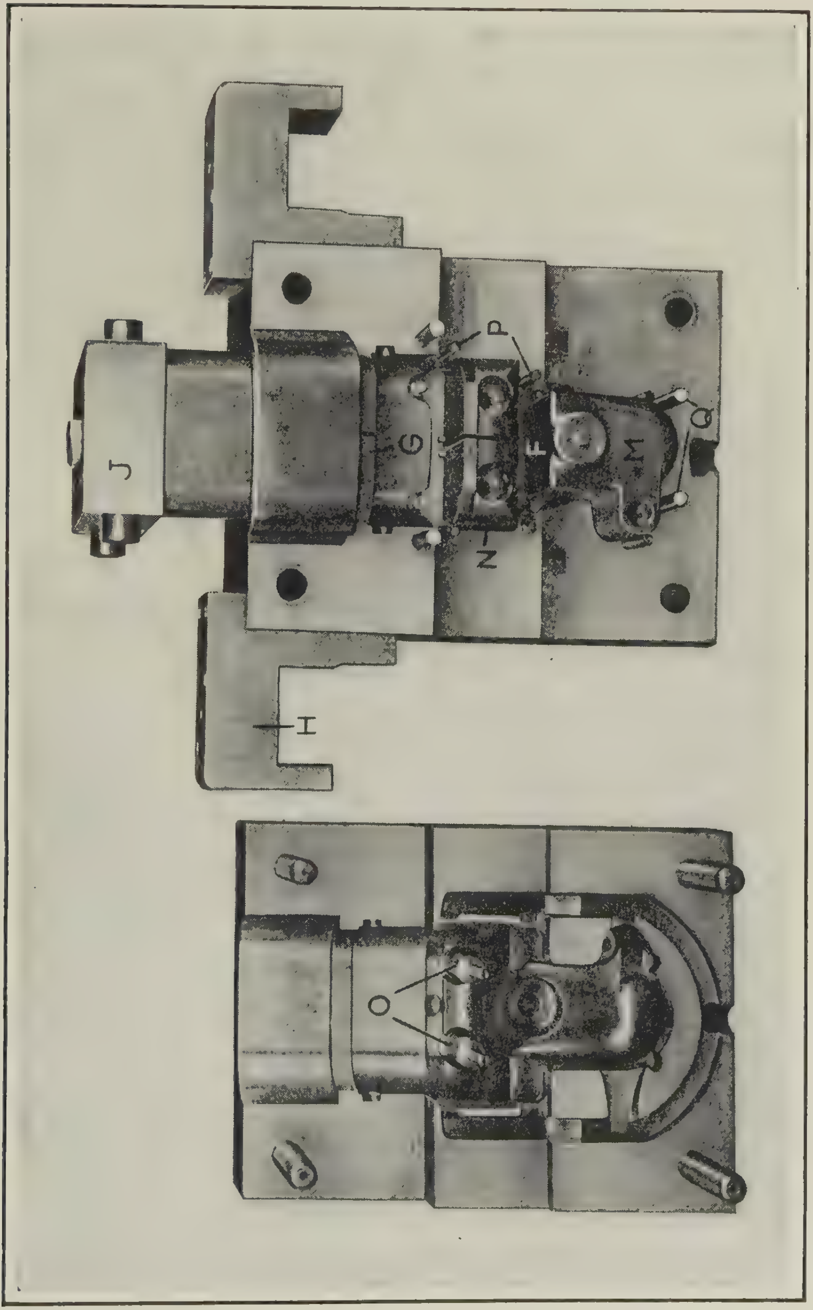


Fig. 20. Another View of the Carburetor Body Dies with the Two Moving Cores of the Movable Die Withdrawn

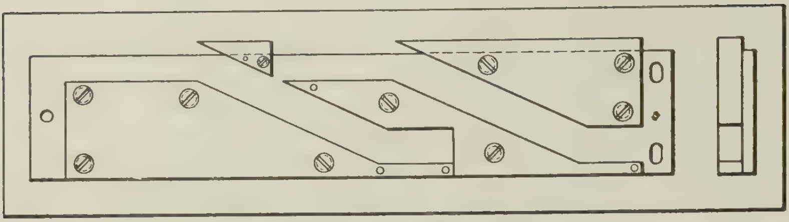


Fig. 21. Typical Arrangement of Cam-blocks Provided on Combination Bars of the Die-casting Machine for Imparting Movement to the Sliding Cores of Movable Dies

carburetor body is illustrative of the accuracy with which die-castings can be produced, as most of the center-to-center distances between holes, and some of the surfaces, must be true to specified dimensions within 0.002 inch. The casting measures approximately 8 by 4 3/4 by 3 1/4 inches; it is made from a zinc-base alloy, and weighs 2 3/4 pounds.

Figs. 19 and 20 show the dies made for producing the part; the stationary die member is at the left in each illustration and the movable die at the right. Pocket *A*, Fig. 18, and the recesses and holes that lead from it are formed by core *F*, Figs. 19 and 20, while the opening within end *B*, Fig. 18, is produced by core *G*. The construction of these cores may be clearly seen in Fig. 22, which shows the details of the movable die.

In Fig. 19 the movable die is shown with the moving cores in the casting positions. Fig. 20 shows this die with the moving members in the positions they occupy when the dies are open. The moving cores are pulled up or down, as the case may be, and the ejector-pins pushed forward. When installed in the die-casting machine, the movable die is supported by brackets *H* from guide bars of the machine.

How the Moving Cores are Operated.—Assuming that the dies are closed so that the sliding parts of the movable die are in the positions shown in Figs. 19 and 22, the four rollers attached to the sides of head *J* will occupy the lowest position on cam paths formed by blocks fastened to two combination bars mounted on the top of the machine (Madison-Kipp automatic). One of these bars is illustrated

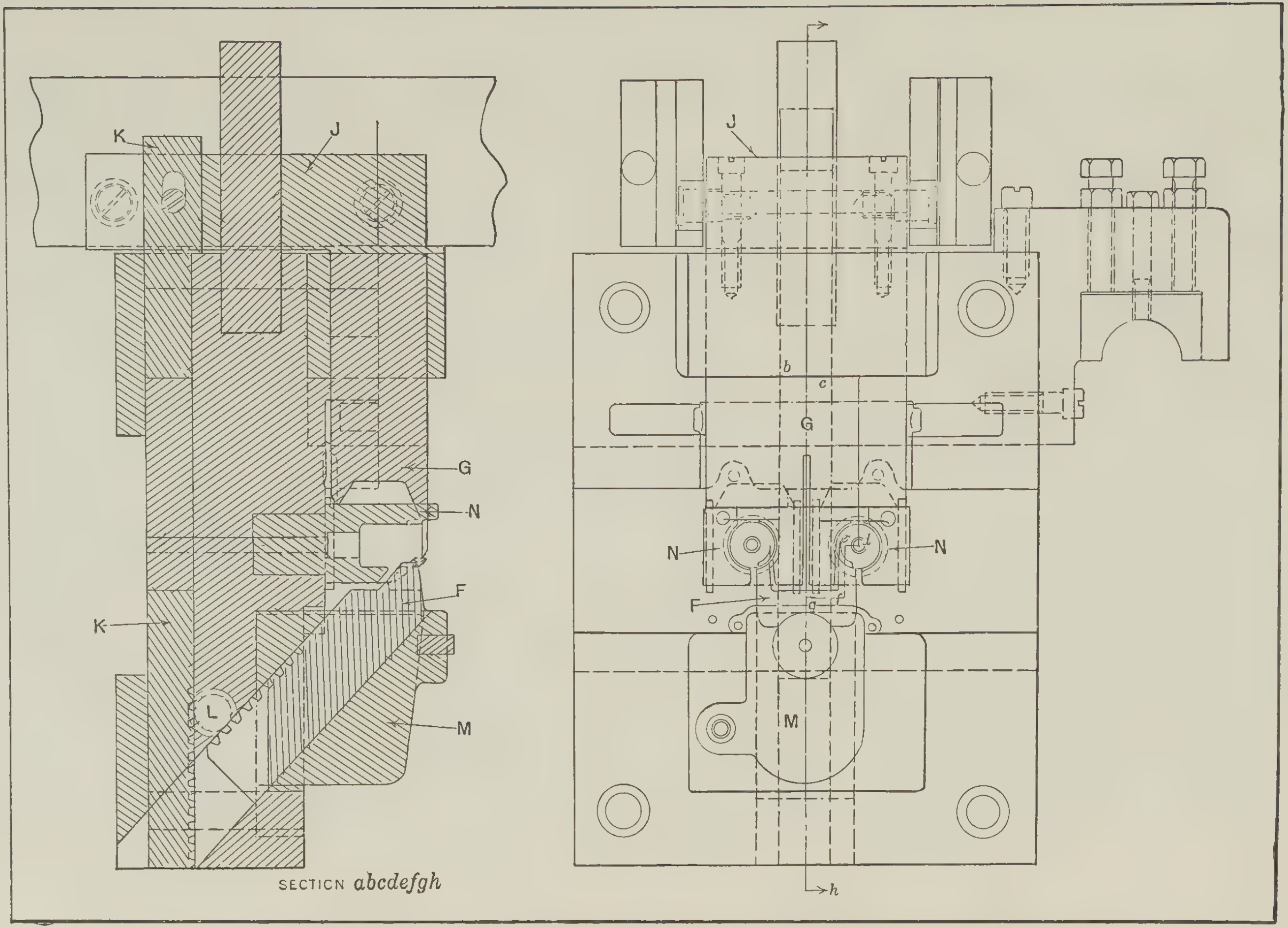


Fig. 22. Construction Drawing, Showing the Means Employed for Moving the Cores that Produce Pocket A, Fig. 18, of the Carburetor Body and the Opening in End B

in Fig. 21. When the casting operation has been completed and the movable die carriage of the machine moves toward the left to open the dies, the rollers of head *J*, Fig. 19, are moved up the cam paths of the combination bars and thus pull core *G* vertically with the head.

When core *G* has been lifted about 3/8 inch, a bar *K*, Fig. 22, attached to head *J*, starts to move upward. Rack teeth at the lower end of this bar engage a long pinion *L* which, in turn, meshes with rack teeth machined on the lower end of core *F*. Thus, as head *J* moves upward, core *F* is withdrawn into the stationary core *M* to release the die-casting, and when the head moves downward to make the dies ready for the next casting operation, core *F* moves upward into the position shown. At *N* may be clearly seen the construction of the stationary cores which form openings *C*, Fig. 18. Core *M* forms the large chamber *D*. The lower end of core *G* is made flat so as to form a firm seat on the shelves formed by the upper surfaces of cores *N*.

From a comparison of the dies in Figs. 19 and 20, it will be obvious that the parting line of the casting is along the center of the oval section of end *B*, Fig. 18, and then runs horizontally to the face seen uppermost at the right in the latter illustration. The parting line follows this face to the lower end of the casting.

Cores *O*, Figs. 19 and 20, of the stationary die, which produce shouldered holes within bosses *E*, Fig. 18, are water-cooled by small channels that lead almost to the outer ends of the slender cores. The stationary die contains grooves or passages leading from the sprue which carry the molten metal to several different places in the die-cavity. Pilot-pins on the stationary die enter bushings in the movable member to insure accurate die registry when the dies are closed.

Means Provided to Eject Casting from the Movable Die.— Owing to shrinkage in cooling, the carburetor body always sticks to the movable member when the dies open. Ejection of the casting is accomplished as the carriage of the machine nears the end of its stroke. At that time, a plate in back of the die, on which eight or ten pins *P*, Fig. 20, are mounted, is held stationary so that the die slides back over the pins, which thus eject the casting.

The ejector-pin plate advances with the movable die as the latter is brought into contact with the stationary die, and so means have to be provided for insuring complete withdrawal of the ejector-pins before the casting operation is performed. This is accomplished by four pins *Q* on the ejector-pin plate, which strike the face of the stationary die and thus force the ejector-pins back as required.

Cam Slots Formed in a Die-Casting by Loose Die Parts.—Loose die parts that are ejected with the work after each operation are the principal feature of the set of die-casting dies illustrated in Fig. 23. These dies are for producing from zinc the washing-machine spider handle shown in Fig. 24. The loose parts are required to produce irregular cam slots in opposite sides of the handle hub to the outline indicated at *Y* in Fig. 25. These cam slots are formed to a depth of 1/8 inch.

Three loose pieces, *A*, *B*, and *C*, respectively, are required to form each cam slot. These pieces are slipped over pins mounted on plate *D* when the latter is out of the die. This plate, with pieces *A*, *B*, and *C* in place, is slipped over core *E* of the stationary die when the movable die is in the withdrawn position. The movable die is then closed against the stationary die for the casting operation.

When the movable die is again withdrawn from the stationary member as the operation is completed, plate *D* and the six loose pieces which form the cam slots are pulled off core *E* by the die-casting. The casting, with the slot-forming parts, is ejected from the movable die by pins attached to plate *F* as the movable die approaches the end of its opening stroke. Plate *D* with its pins is then withdrawn by hand from the casting to permit the easy removal of pieces

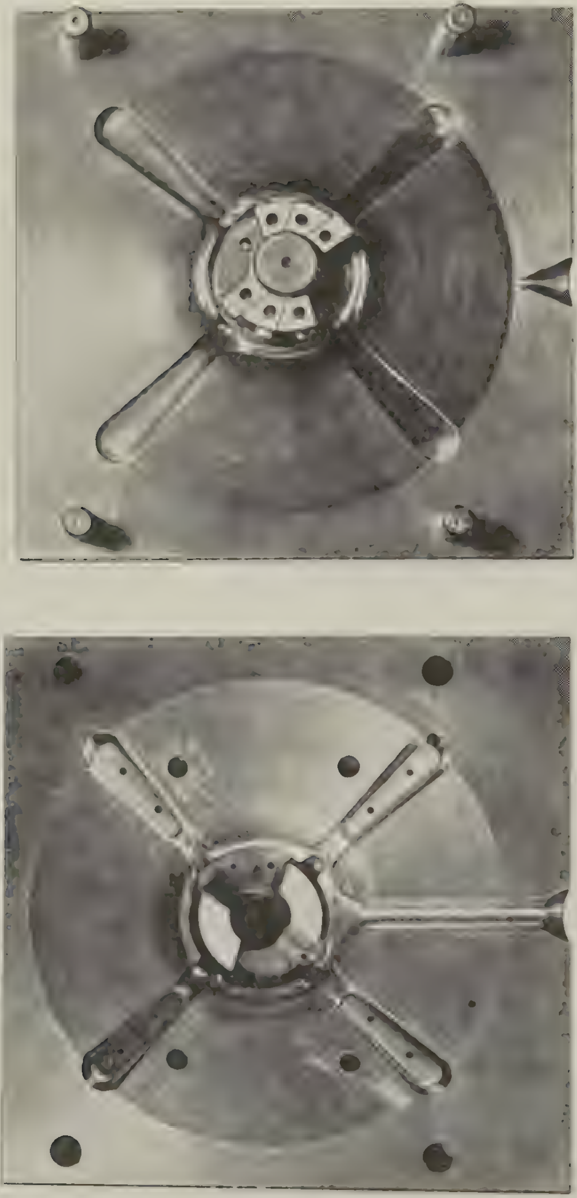


Fig. 23. Die-casting Dies Made with Seven Loose Pieces to Permit the Forming of Irregular Cam Slots in Spider Handles.

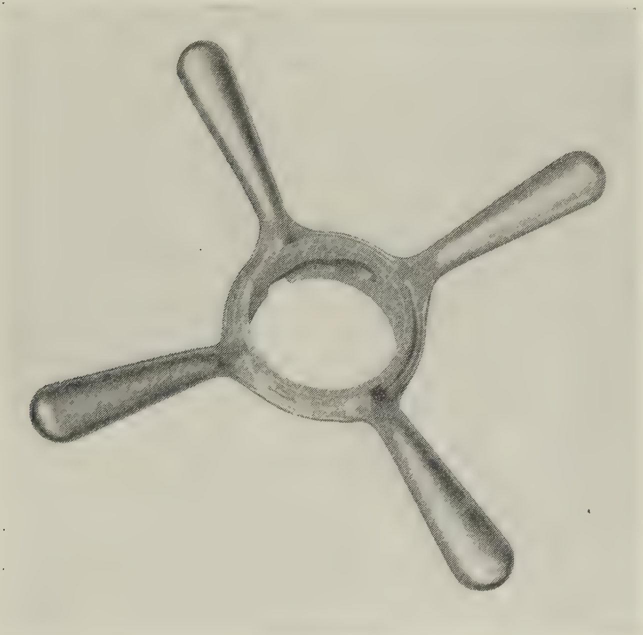


Fig. 24. Spider Handle for Electric Washing Machine which is Cast from Zinc in the Dies Shown in Fig. 23.

A, B, and *C*. Piece *C* of each set is first withdrawn from the casting, then piece *B* and finally piece *A*. Several sets of these loose pieces and holding plates are kept on hand so that they can be assembled and disassembled while another operation is in process.

Pin *H* locates plate *D* radially on the stationary die, so that the loose pieces will register properly with slotted block *J* when the dies are closed. As the movable die approaches the stationary die, four pins *K* return plate *F* and the ejector-pins into the positions shown.

The spider handle formed in these dies is approximately 11 1/2 inches in diameter across the ends of the spokes. A generous gate was provided to carry the required amount of molten zinc to the die-cavity. At the point where the metal actually enters the cavity, the gate is about 3 inches

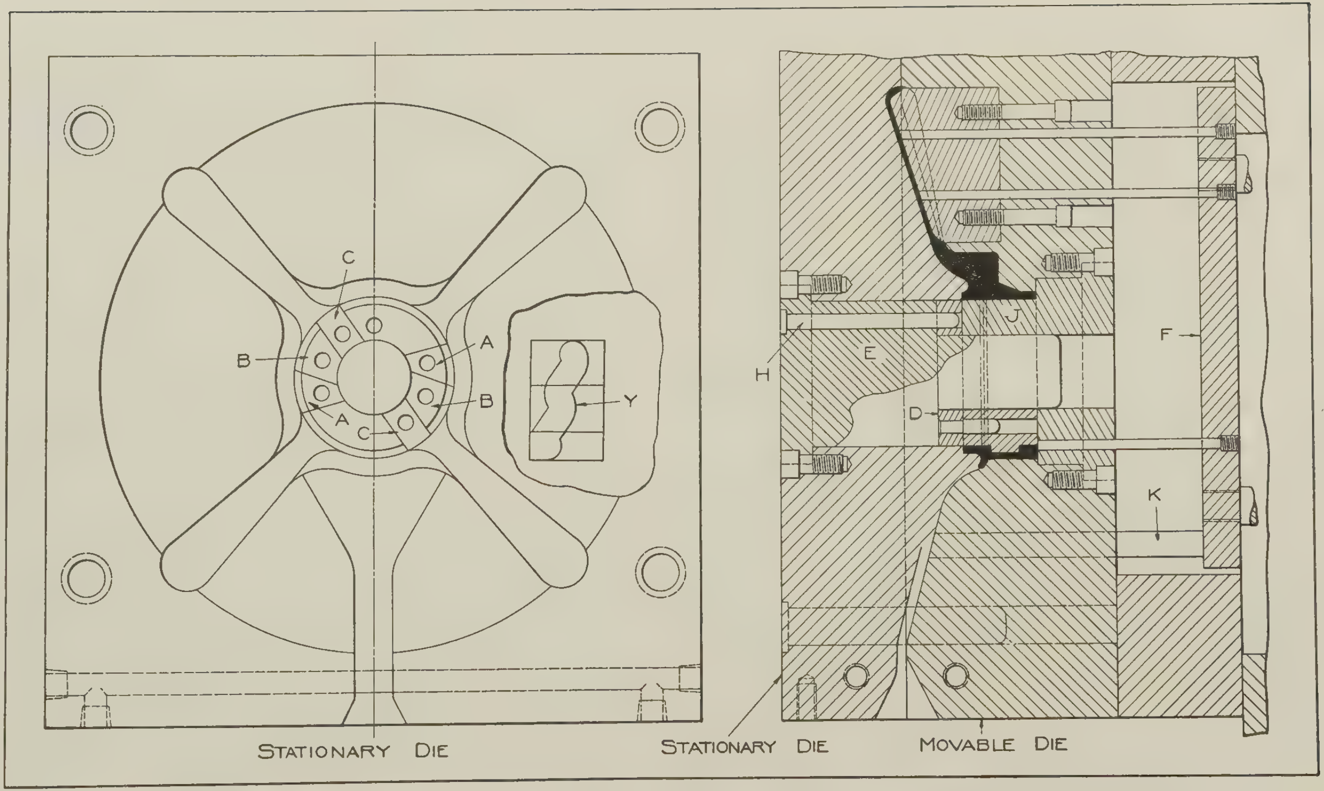


Fig. 25. Loose Pieces which Form Two Cam Slots of the Outline Indicated at **Y** and are Ejected with the Casting are the Principal Feature of These Spider-handle Die-casting Dies.

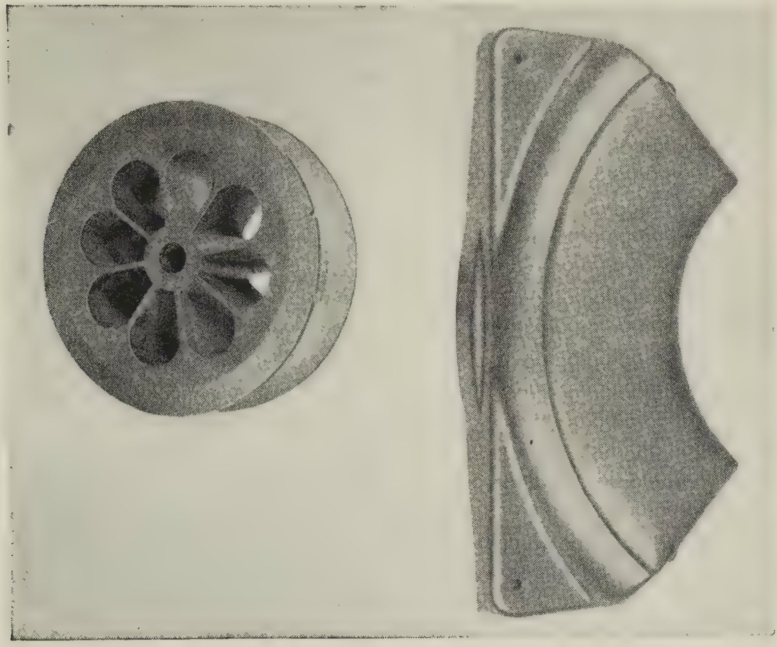


Fig. 26. Die-castings Made from a Magnesium Alloy that is Approximately One-third Lighter than Aluminum.

wide by 0.035 inch deep. These dies are used on an automatic die-casting machine. About two shots can be made a minute.

Dies Used for Magnesium Die-Castings.—Magnesium is becoming increasingly popular for use where it is important to use castings of minimum weight. Magnesium is approximately one-third lighter than aluminum, and in the cast condition it has a tensile strength comparable to that of aluminum. For instance, non-heat-treated castings of Dowmetal (a magnesium alloy) have a tensile strength of 28,000 pounds per square inch, while heat-treated Dowmetal castings have a tensile strength of 35,000 pounds per square inch.

Two die-castings of Dowmetal are shown in Fig. 26. The example at the left is a reel on which wire only 0.0003 inch

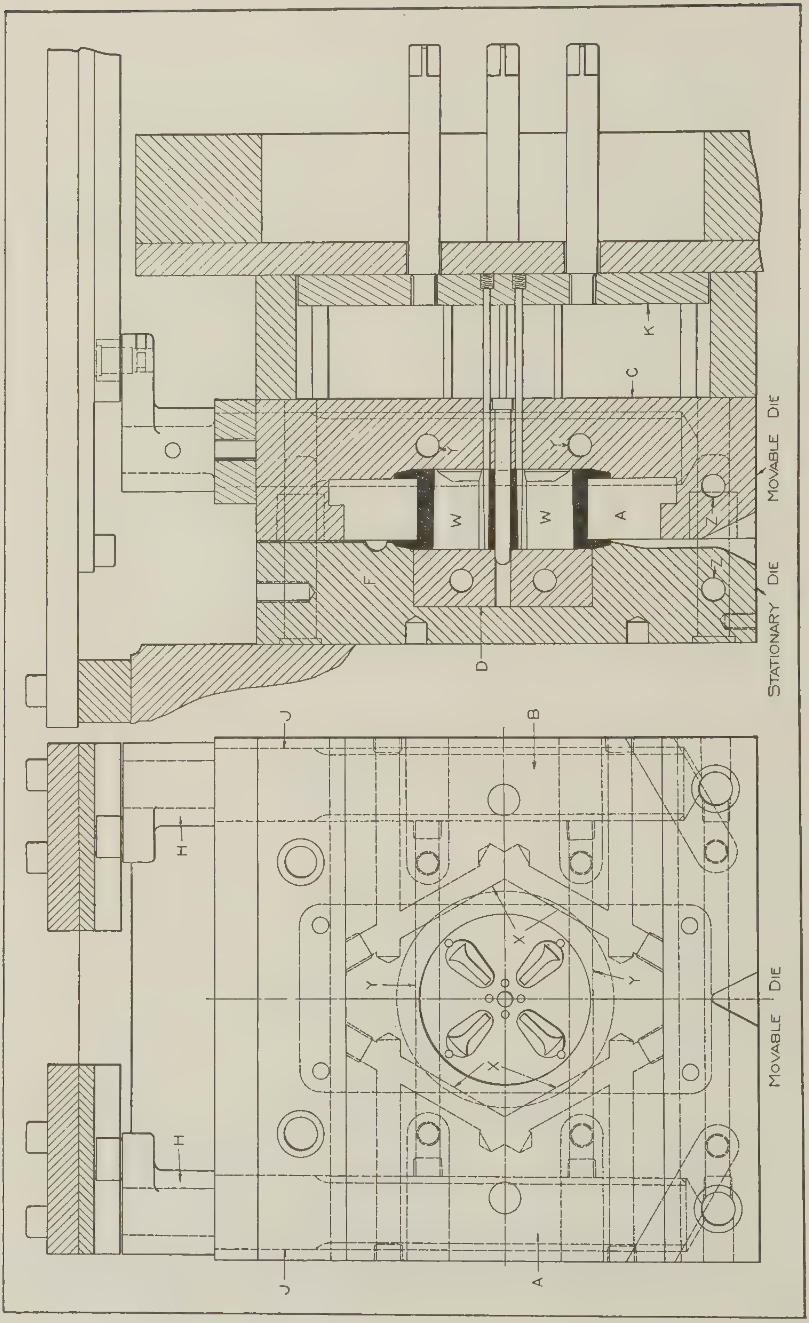


Fig. 27. Dies which Produce the Magnesium Reel Shown at the Left in Fig. 26. Extensive Provisions for Water-cooling are a Feature of These Dies Necessitated by the High Casting Temperature of Magnesium.

in diameter is wound. Sand castings of aluminum were formerly used in this application. They collapsed due to the weight of the wire revolving at high speed, but the magnesium die-castings stand up satisfactorily under this service. These reels have a maximum diameter of 5 1/8 inches and they are 1 7/8 inches wide.

The typewriter top plate shown at the right in Fig. 26 is about 11 inches long by 5 inches in maximum width. Its thickness varies between 3/32 and 1/16 inch.

Dies for Magnesium Castings Require Extensive Water-Cooling.—Both of the magnesium die-castings illustrated in Fig. 26 are produced in automatic machines built by the Madison-Kipp Corporation. In the die-casting operation, the melting pot of these machines is held at a temperature of 1350 degrees F. Such a high temperature necessitates careful provision for constant cooling of the dies by means of water. Both sets of dies were made entirely from a high grade of tool steel.

In Fig. 27 may be seen the precautions taken to insure that the temperature of the dies used in producing the reel will not become excessive. Holes *X* are provided in two slides *A* and *B* of the movable die which form the cylindrical surface of the reel. These slides open sidewise when the movable die is withdrawn endwise from the stationary die. Holes *Y* are drilled in block *C* of the movable die, in back of the two sidewise operated slides. Holes *Z* are provided completely across the bottom of the stationary and movable dies in the vicinity of the sprue, while similar holes are provided around block *D* of the stationary die.

Eight Radial Cores Made Integral with One Block.—The eight radial openings of the reel are produced by integral cores of block *D*, which extend into the die-cavity as indicated by letters *W*. The shape of these cores will be understood from the photograph of the reel reproduced in Fig. 26. Each core extends about 2 inches above the block

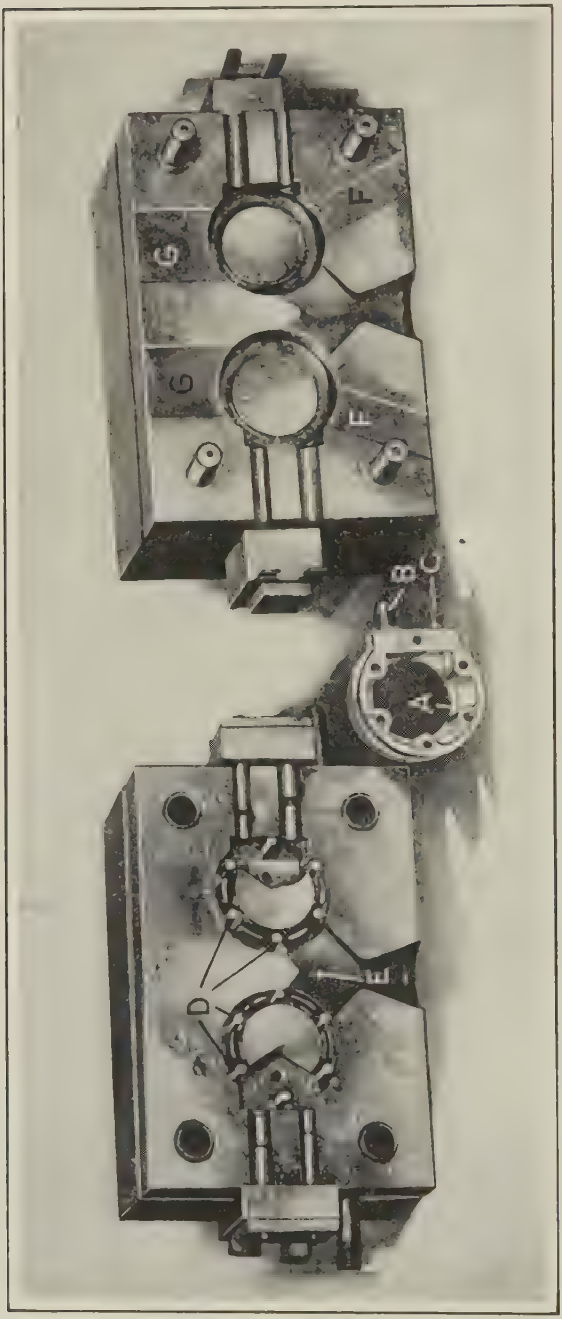


Fig. 28. Construction of Die Used in Simultaneously Casting Two Parts with Threaded Brass Inserts.

proper and it tapers from 1/32 to 3/64 inch from top to bottom. The space between the walls of the successive cores varies from 1/16 to about 1/8 inch in width.

The central hole in the reel is formed by a core of the movable die, while the hub is formed by the space between this central core and eight cores *W* of block *D*. The two flanges of the reel are produced by depressions in blocks *C* and *F*.

How the Part is Ejected from the Dies.—When the movable die is withdrawn from the stationary member, the casting is held to the movable die by slides *A* and *B*, Fig. 27, these slides pulling the casting from cores *W*. As the movable die recedes, rollers attached to crank-arms *H* follow cam paths of bars mounted on top of the machine and turn these crank-arms, as well as shafts *J* to which they are fastened. Shafts *J* have spur gear teeth for the greater part of their length, which engage rack teeth cut on the back of slides *A* and *B*. Thus, as the crank-arms are swiveled on their axes, slides *A* and *B* are opened sidewise from the casting.

During the last two inches of the opening stroke of the movable die, plate *K* is held stationary. This causes a series of long slender pins attached to the plate to force the casting off the central core and from the die. Plate *K* with its ejecting-pins, as well as slides *A* and *B*, are returned into the positions shown when the movable die is again closed against the stationary member.

Die for Part Having Two Threaded-Plug Inserts.—Inserts of brass, steel, and other metals can be cast in parts for a variety of purposes. The inserts may be of any metal that has as high a melting point as the metal being cast. Sometimes die-cast pieces are used as inserts. In Fig. 28 are shown the die members used in producing part *A*, which is cast with two threaded plugs in place, as seen at *B* and *C*. The die is of unusually simple construction, with a parting

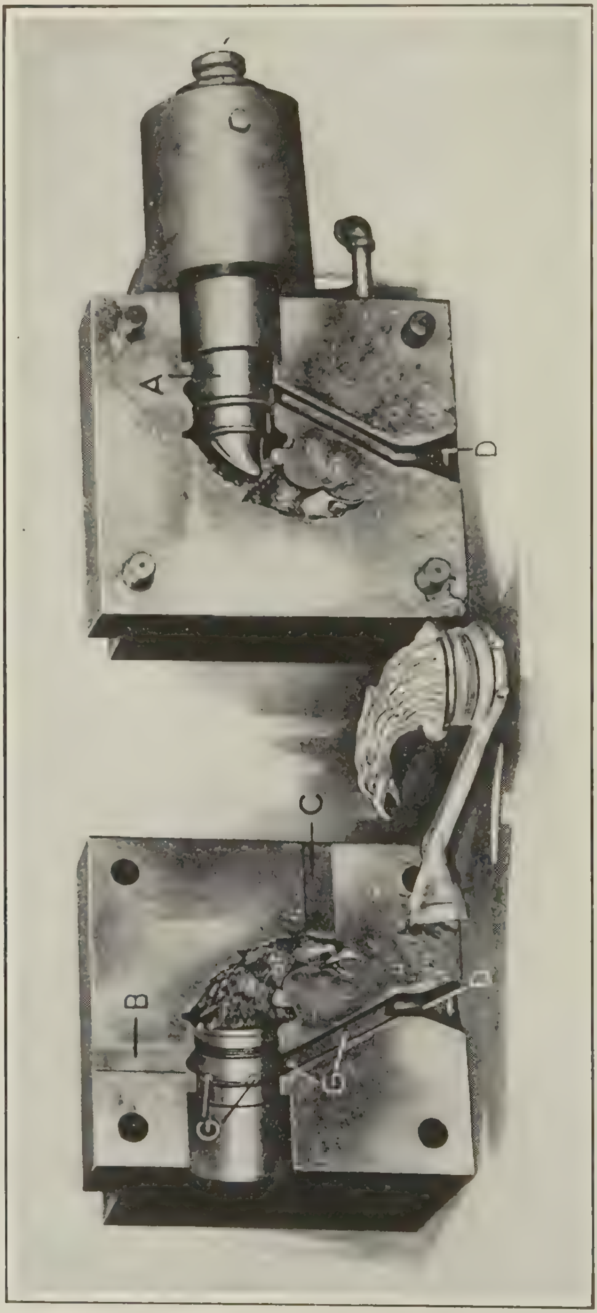


Fig. 29. An Interesting Feature of this Die, Formerly Used to Produce Artistic Radiator Caps, is the Fine Detail Which is Faithfully Reproduced on the Finished Casting

line running along the middle of the part, and casts two pieces simultaneously. The inserts are placed in position on the face of the stationary die member when the die is open. Shoulders on the inserts guard against metal being cast on the threads.

Six holes are produced around each casting by the use of core-pins such as seen at *D*. Ejector-pins are visible beside each of these cores and at *E*. Air vents may be seen at *F* and *G* on the stationary member. Unusual savings have been obtained by die-casting this part, as the drilling of nine holes is eliminated, as well as two threading operations, a turning operation, facing of the two sides, and machining of the outside contour.

Inserts are sometimes made with a circular groove close to the end that is held in the metal, and this end is knurled. Thus when the molten metal fills the groove, it securely locks the insert in place and by filling the knurling, it prevents the insert from turning. Inserts can also be made with lugs that prevent them from being pulled out of the die-casting or turned. The casting shown in Fig. 28 is made of a zinc-base alloy.

Many dies are built for producing a number of parts simultaneously, with or without inserts. For instance, various ornamental handles, such as are used on automobile doors, are cast eight at a time with steel-shank inserts.

Die for Radiator Cap which is Reinforced with Brass Forging.—The die-casting process lends itself especially well to the production of many metal objects of artistic design, such as radiator caps supplied on automobiles. Heads of birds, for instance, can be produced so that the various details of the feathers are very distinct. Fig. 29 shows a die employed for casting a cap having the head of an eagle, the stationary member being shown at the right and the moving member at the left. Only one core is required, as shown at *A*. It is operated from one side of the die and is used to form the cavity on the inside of the casting.

A unique feature of the casting formed with this die is that the bill of the eagle is reinforced with a small brass forging. This forging is placed by hand on the shoulder of the stationary die that is formed by the open mouth of the bird.

External threads are cast on this part. Vents to allow the escape of air may be seen at *B* and *C* of the moving die member, and a generous gate is seen at *D* on both members. Four holes in the moving member slip over pilot-pins on the stationary part to insure accurate registration of the two die halves for each operation. Holes through which the ejector-pins operate may be seen at *G*. The gate metal and flash left on this casting are readily removed by the use of band saws and disk grinding machines. The casting is made of a lead-base alloy.

Accuracy of Die-Castings.—It is possible to produce very accurate die-castings, but the accuracy depends upon the size of the casting, the design, the accuracy of the die itself, the accuracy of the allowance made for shrinkage of the metal, and the kind of alloy used for the die-casting. Average tolerances for tin-base alloys may have a minimum value of about plus or minus 0.0005 inch per inch of casting diameter or length and about plus or minus 0.001 inch for zinc- and lead-base alloys. These unit tolerances per inch of length or diameter, however, do not remain constant over a wide range of dimensions, and they may be reduced one-half or more per inch when a casting is relatively large, assuming that accuracy depends chiefly upon the shrinkage allowance and there is practically no change in shape due to shape of casting or lack of uniformity in cooling.

Almost any dimensional tolerances can be held on die-castings, but the closer the tolerances, the more carefully must the die be made, and the closer must be the inspection of the product.

Today, commercial aluminum-alloy castings are generally produced within limits of plus or minus 0.0015 inch per linear inch. When the shrinkage of a particular casting is determined by successive trials and reworking of the dies, even closer limits can be maintained on dimensions of 3 inches or more. Dimensions perpendicular to the parting line are maintained within limits of plus 0.010 inch in the largest castings, while on smaller pieces the limits are generally 0 to plus 0.003 inch. For special purposes, however, dimensions have been held to limits of plus or minus 0.001 inch across the parting line.

Tolerances that are far beyond the possibilities of sand casting can be met by the die-casting process. As an example, it may be mentioned that housings for electric clocks are being cast with seven cored holes, of which the center-to-center distances must be true within plus or minus 0.001 inch. These clock housings are 4 inches long by 3 inches wide and have walls only 0.042 inch thick. The diameters of the cored holes must be to size within 0.0005 inch.

Die-casting die designers should, however, bear in mind that die costs mount appreciably when close tolerances are specified. Dimensions in thousandths of an inch should always be avoided when fractional dimensions will serve the purpose equally as well.

Product Designers Should Consult Die-Casting Experts.—In designing die-casting dies, many questions arise that can be decided only upon the basis of considerable experience in the art. Before settling upon all the details of a part that is to be cast in dies, the product designer would find it advantageous to consult with a die-casting specialist. The latter can usually suggest slight changes that will greatly reduce die cost and at the same time result in better castings. For example, sometimes it may be cheaper to drill a hole than to core it.

One thing that the product designer should bear in mind is that when decimal dimensions and close tolerances can be avoided, the cost of dies will be greatly decreased. Some engineers seem to think only in terms of plus or minus

0.001 inch, when larger tolerances will suit the purpose as well.

The pronounced progress made in die-casting practice during recent years has largely resulted from the recognition of the fact that this process belongs to the die designer and diemaker rather than to the foundry. Mixing metals was once an important phase of successful die-casting, but with the present-day availability of ready mixed alloys of approved purity and specification, the important problems of die-casting have resolved themselves into those of providing dies of proper design for use on modern casting machines. Die-castings today are, therefore, definitely the work of the designing engineer and the diemaker; the toolroom has become an indispensable auxiliary of the die-casting department.

Complicated parts can now be die-cast with comparative ease because of the complete mechanization of the die-casting process. Dies that are fully automatic, even to the operation of numerous cores, have proved successful for a large variety of parts. An outstanding advantage of the automatic dies is that their mechanical movements can be accurately timed and positively carried out in the most ideal sequence for the individual part. Automatic dies have also done away with arduous labor, speeded up die-casting, and eliminated the uncertainty and hazards of the human element.

Multiple Cavity Dies for Duplicate Castings

If parts are not too complicated in design and especially if large or rapid production is essential, dies of the multiple type are used. Dies of this type have two or more cavities so that two or more castings can be produced at each "shot" or injection of molten metal into the dies. Duplicate castings are commonly produced in these multiple dies, although in some cases several parts of different size and shape are cast simultaneously in the same set of dies.

Die-Casting Two Typewriter Ribbon Spools Simultaneously.—The die-casting process has been applied extensively in the manufacture of zinc, aluminum, lead, and brass parts that were formerly cast in sand molds. However, parts that consist of one or more steel stampings can often be replaced with die-castings to considerable advantage. Fig. 1 shows a die-cast ribbon spool which is entirely of zinc, except for a threaded steel tube that is cast in place. This spool was formerly made of several stampings which required a number of power-press operations for their production. Additional assembly operations were required.

The die-cast spool is made two at a time in one operation by means of the automatic dies illustrated in Figs. 2 and 3. In Fig. 2, the movable die is seen at the left and the stationary member at the right. The interior of the large end of each spool is formed by a core *A* (Fig. 3) which is attached to a sliding holder *B*. When the movable die is against the stationary member as in an operation, an angular hole in each slide *B* is engaged by an angular pin *C* fixed to the

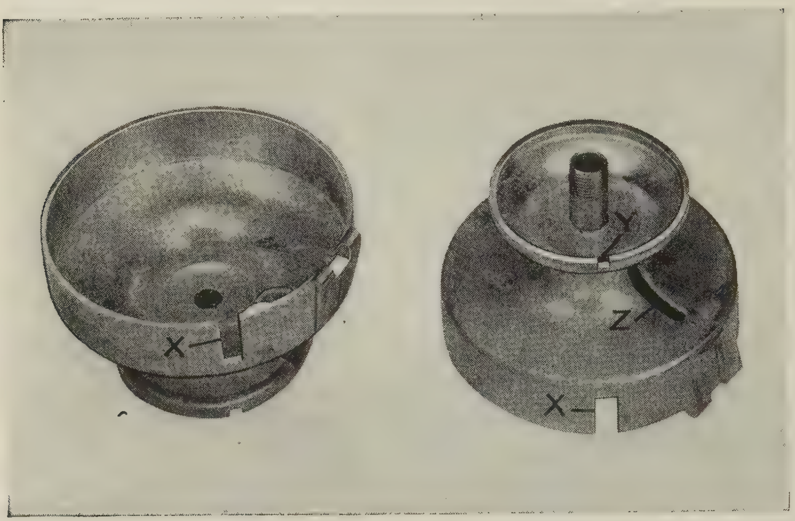


Fig. 1. Zinc Die-casting with a Threaded Steel Tube which has Replaced a Part Formerly Made of Several Stampings.

stationary die. As the movable die is withdrawn from the stationary member at the end of an operation, each holder *B* is moved vertically about 1 1/4 inches as it slides off pin *C*. This vertical movement is sufficient to bring the lower end of core *A* clear of the upper end of the casting. Each holder *B* is held in the raised position by means of a spring detent *E*. Both holders are fastened to the face of the movable die by housings *D*.

The opposite end of each ribbon spool is formed by a core *F* which is attached to a holder *H*. This core is lowered by means of an angle-pin *J* when the movable die is withdrawn from the stationary member. The angle-pin method of operating cores is extensively used by the Madison-Kipp Corporation when the core movement is comparatively short, say not more than two inches.

In Fig. 3, the threaded steel tubes are shown at *W* as they are positioned in cores *F* for the casting operation. The tubes are inserted when the movable die is withdrawn from the stationary die at the end of each operation.

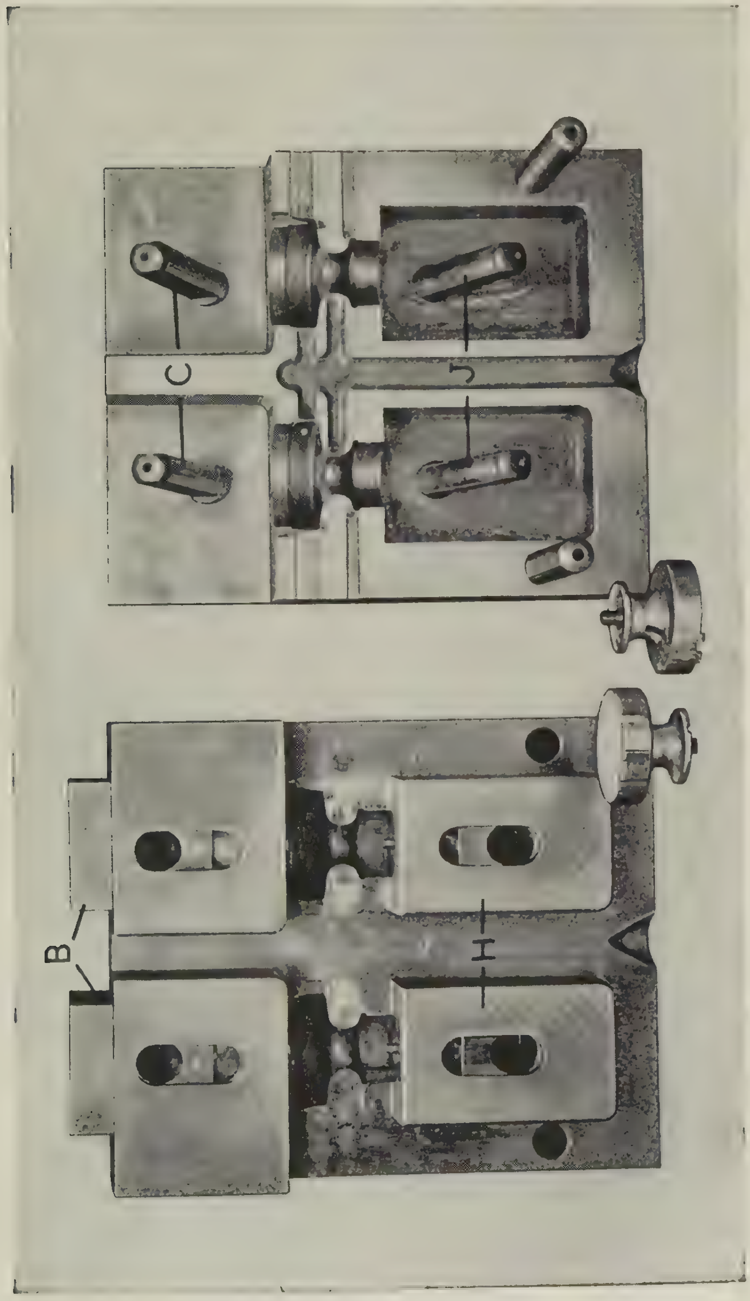


Fig. 2. Dies which Produce Two Typewriter Ribbon Spools Complete with Threaded Steel Inserts in One Operation.

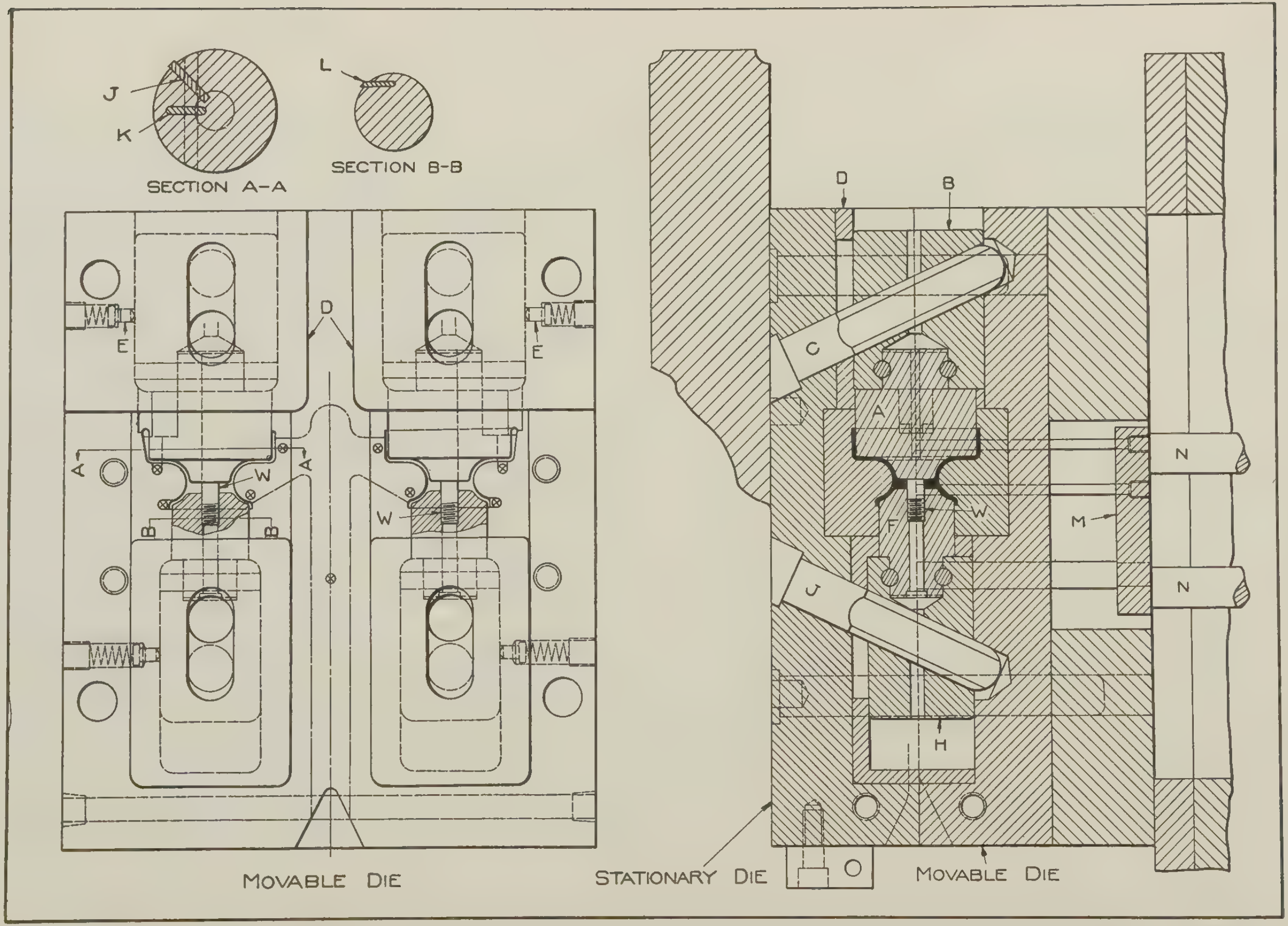


Fig. 3. Four Cores Moved Vertically by Angle-pins are a Feature of These Dies which Produce the Typewriter Ribbon Spool Shown in Fig. 1

From Fig. 1 it will be seen that the spools are cast with a slot *X* in the large flange, a slot *Y* in the small flange and a rectangular hole *Z* in the body portion. Slot *X* is produced by a core *J* which is shown in section *A-A*, while opening *Z* is produced by core *K*. Slot *Y* is formed by core *L* in section *B-B*.

Ejecting the Two Die-Castings.—Standard means are employed for ejecting the finished pieces from the movable die, that is, by long slender pins attached to plate *M*, Fig. 3. These pins extend through the die parts to the cavities in which the ribbon spools are cast. Plate *M* is stopped near the end of the movable die stroke as rods *N* contact with a fixed member of the machine. Then the die members slide along the stationary ejector-pins fastened to plate *M* so that these pins force the castings from the die. Coil springs around the outer ends of rods *N* return plate *M* to the casting position as the movable die is again closed against the stationary die.

The ejector-pins do not actually contact against the spool castings. Instead, the dies are so made as to permit the formation of small "ears" at several points around the castings. The ejector-pins exert pressure against these ears. The ears are afterward trimmed off so that with this arrangement there are no marks of ejector-pins on the finished castings. In the left-hand view, the ejector-pins are indicated by crossed lines. One of the ejector-pins bears against the metal cast in the gate that carries the molten metal to the two cavities.

From four to five shots can be made a minute with these dies. Since two castings are made per shot, this means a production between 400 and 500 pieces an hour even with an allowance of 10 minutes' non-productive time per hour. The life of the dies should be long enough to permit a total production of at least one million pieces. The castings are of zinc.

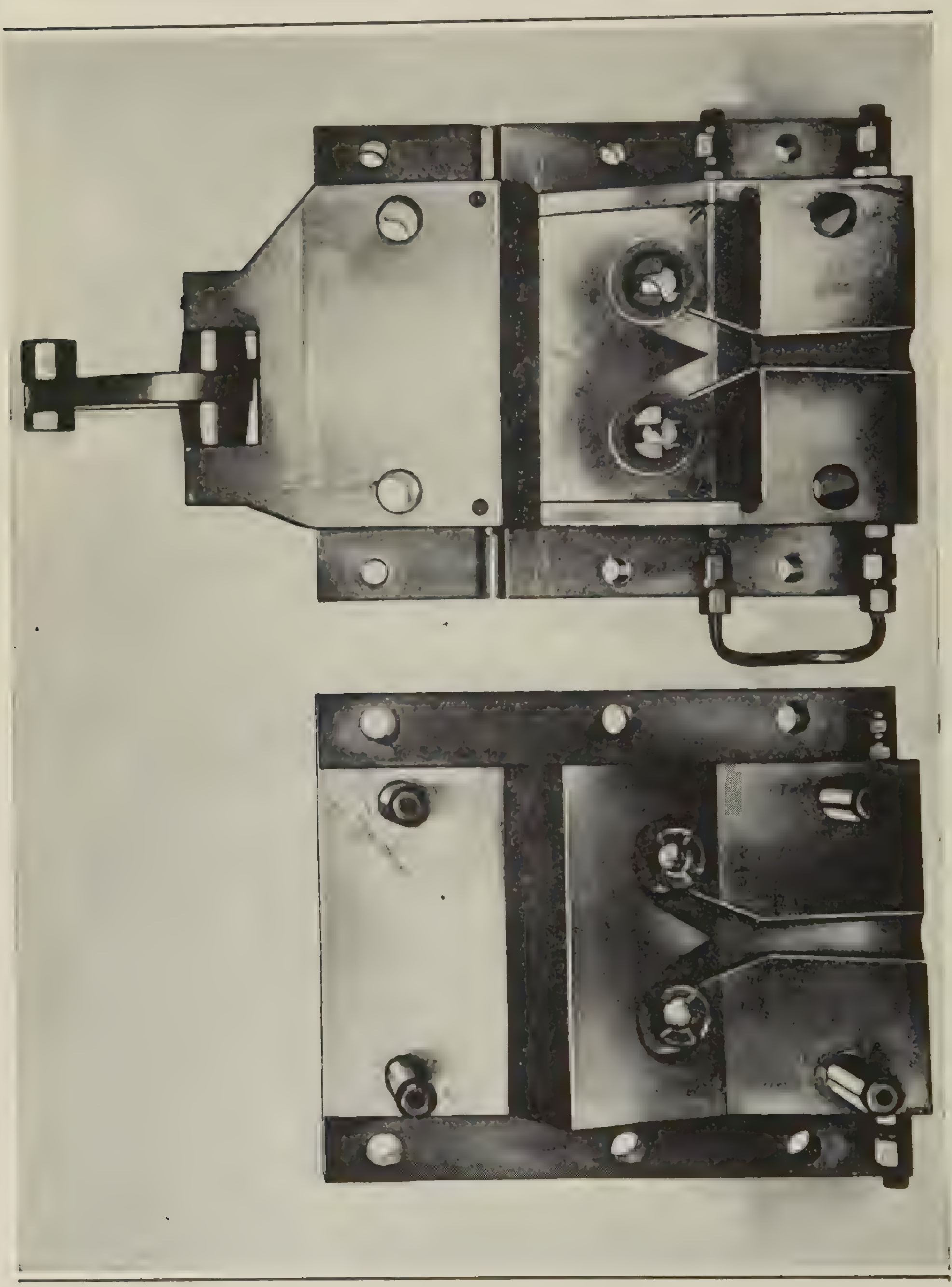


Fig. 4. Dies for Casting Part Shown at B, Fig. 5. Movable Die has Two Sets of Interlocking Cores.

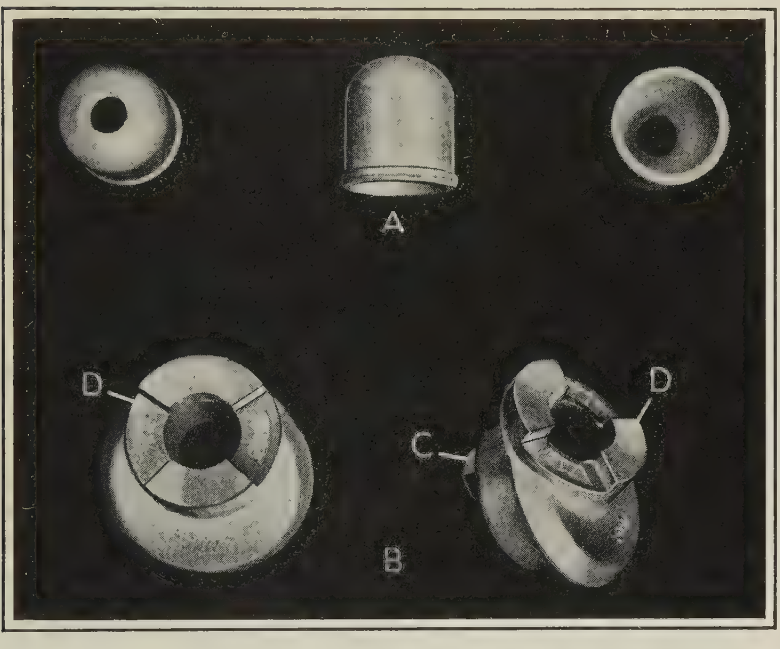


Fig. 5. Small Zinc Castings Produced at High Rates of Production by Means of the Dies Illustrated in Figs. 4 and 7.

Multiple Dies Equipped with Interlocking Cores.—Interlocking cores are the principal feature of the set of die-casting dies illustrated in Fig. 4, which is employed for producing the small eccentric piece shown at *B*, Fig. 5. These interlocking cores, and the ejector-pins as well, are operated automatically by means of mechanism embodied in the movable die. Motion is imparted to this mechanism through stationary cam-blocks attached to a combination bar mounted on top of the Madison-Kipp die-casting machine for which these dies were designed. The locating of the core-operating mechanism in the dies themselves, which is a feature of all the dies made for these machines, reduces the die space to a minimum.

The pieces produced in the dies shown in Fig. 4 are approximately 1 3/8 inches in diameter by 1 1/8 inches long. They are cast from zinc at the rate of sixteen pieces or

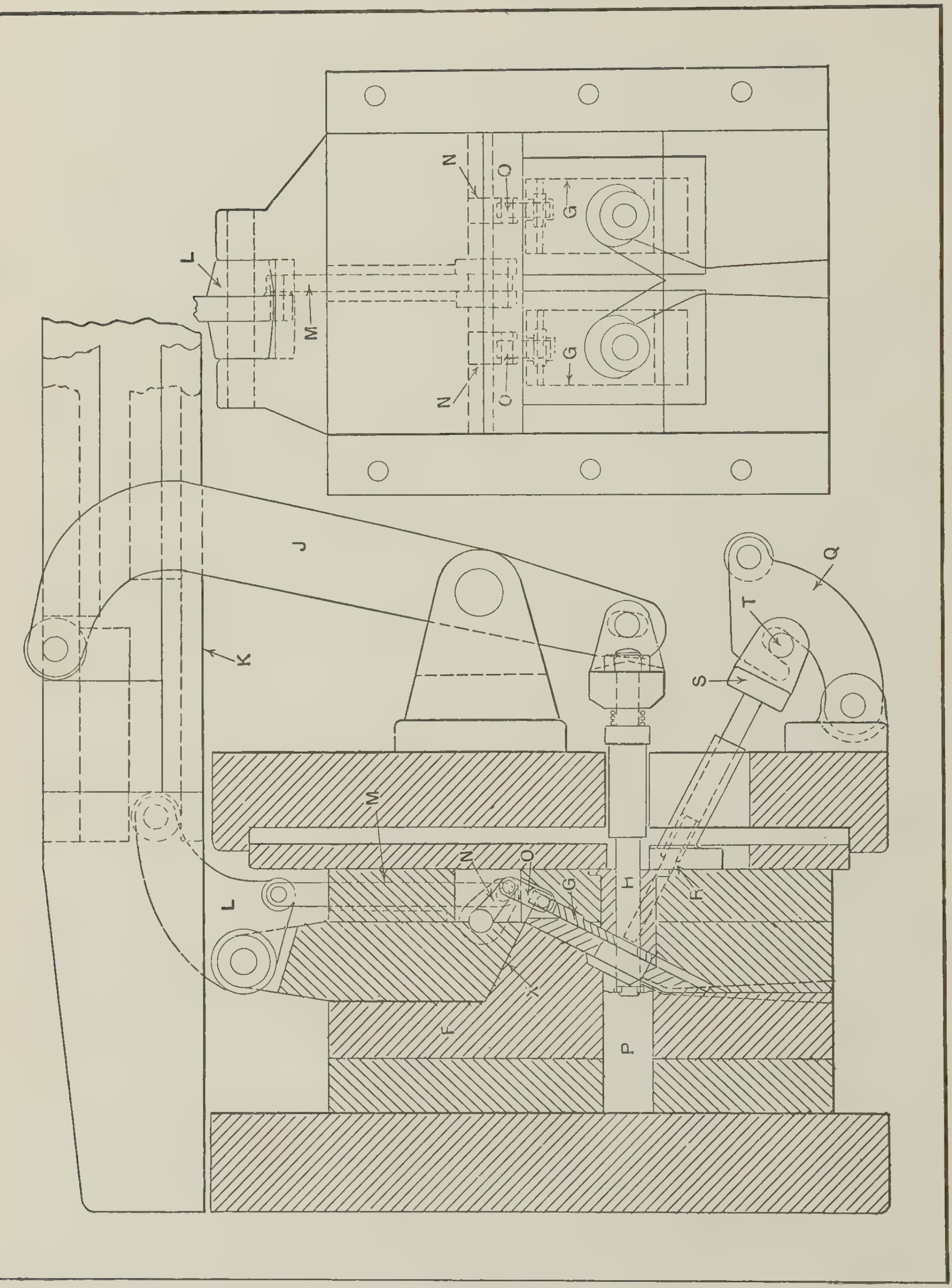


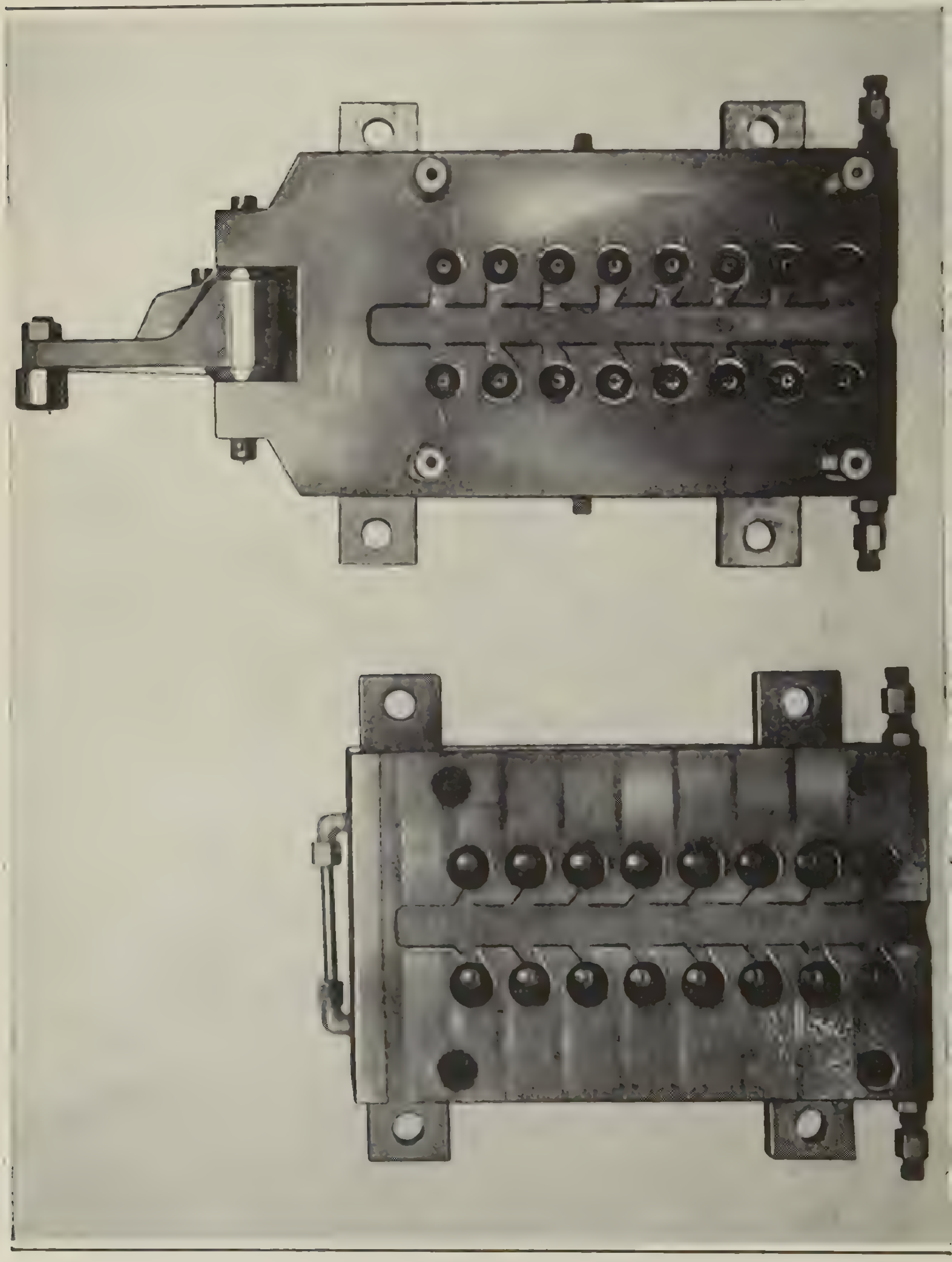
Fig. 6. Mechanism for Moving Four Interlocking Cores and Two Ejector-pins of Movable Die

eight "shots" per minute. Approximately 1,000,000 pieces have been produced from these dies with little wear. The molten metal is forced into the die-cavities under a pressure of from 250 to 300 pounds per square inch. In Fig. 6, which illustrates the construction details, it will be seen that the movable and stationary dies meet along line *X*, part *F* being the stationary die. The view at the right in this illustration shows the face of the movable die.

Mechanism for Operating the Interlocking Cores.— Lug *C* of the part, as indicated in Fig. 5, is dovetailed and thus requires the use of a core plate *G*, Fig. 6, which must be moved at an angle. When the movable die is advanced toward the stationary die preparatory to an operation, this core must be shifted into the position illustrated before core *H* can be moved through it horizontally to form the hole in the casting. Since there are two identical cavities in the dies, as seen in Fig. 4, there are, of course, two cores *G* and two cores *H*.

When the movable die recedes from the stationary die at the end of an operation, lever *J* is swung on its pivot as a roller at the upper end is carried along the path formed by cam-blocks on the combination bar *K* at the top of the machine. Lever *J* is connected through a rod to the outer ends of the two holders to which cores *H* are attached, and hence this movement of lever *J* causes the cores to be withdrawn horizontally. Directly afterward, bellcrank lever *L* is swiveled on its pivot as the roller attached to the upper end of the lever passes along a second path of the cam-blocks on bar *K*. The swiveling of lever *L* causes rod *M* to be lifted, which, through links *N* and *O*, pulls cores *G* upward as required.

When the movable die advances to the stationary die preceding an operation, all these parts are operated in the reverse direction to bring cores *G* and *H* to the position illustrated. Two cores *P*, which form face *D*, Fig. 5, of the casting, are immovably fixed in the stationary die.

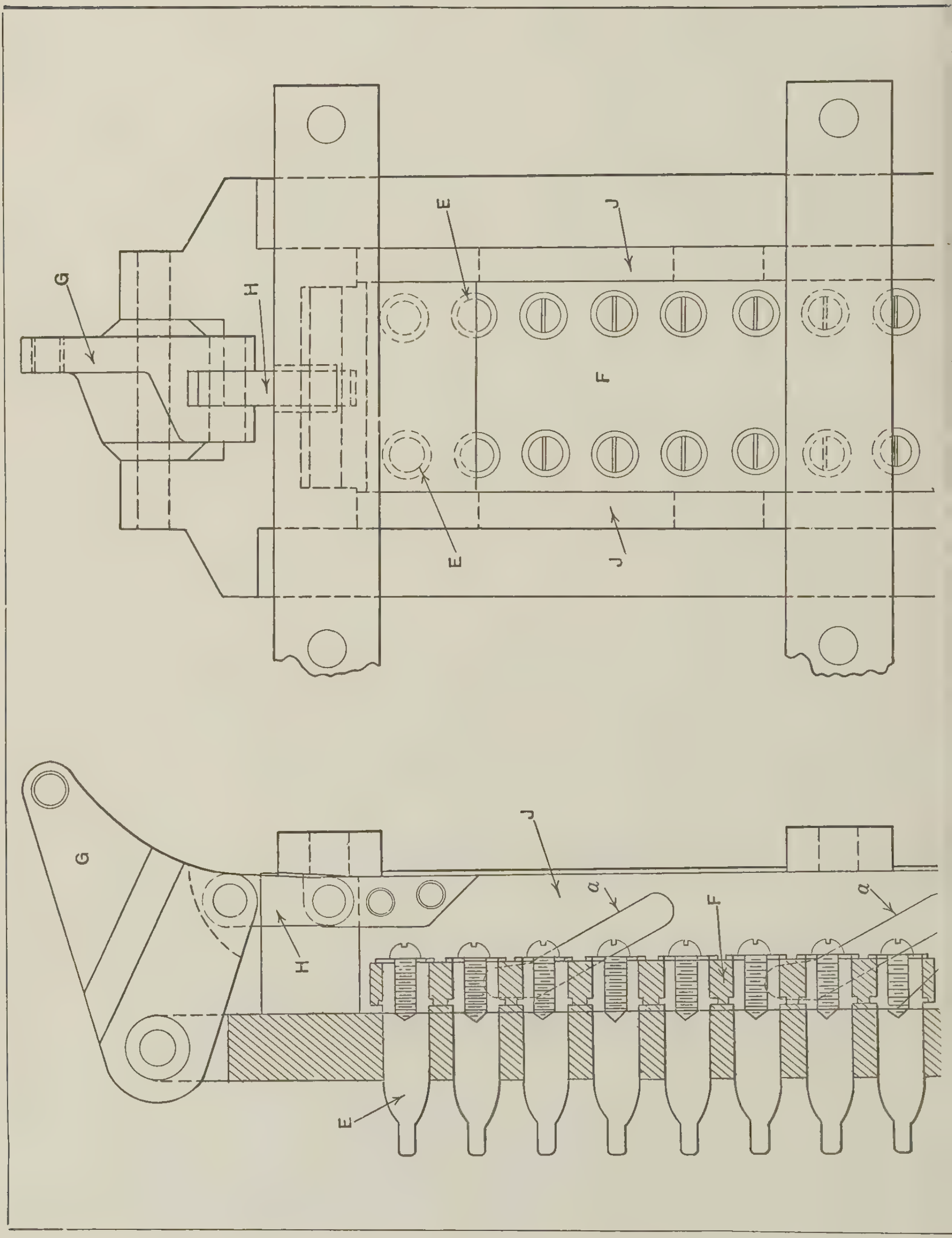


Arrangement of the Ejector Mechanism.—As the movable die carriage nears the end of its return movement from the stationary die, a roller fastened to the right-hand end of link *Q*, as shown in Fig. 6, strikes a stop on one of the guide bars of the die-casting machine. Thus, as the carriage continues to withdraw, link *Q* is swiveled upward on its axis and holds an ejector-pin *R* stationary in each cavity, so that the die proper can slide back along pins *R*. As the castings reach the two ejector-pins, they are forced out of the die-cavities. Rod *T* connects the two ejector-pin holders *S* so that both are actuated by link *Q*. This mechanism operates in the reverse manner to remove the ejector-pins from the die-cavities when the dies are being closed. Pipe connections are provided on both dies to provide for the circulation of water for cooling purposes.

Dies for Casting 128 Cups a Minute.— Small zinc cups of the type shown at *A*, Fig. 5, are cast at the rate of 128 per minute in the dies illustrated in Fig. 7. These cups are approximately 7/8 inch long by 3/4 inch in diameter and have a hole that tapers down from 5/8 inch in diameter at one end to 1/4 inch in diameter at the opposite end. Sixteen cups are produced with each "shot" of molten metal into the dies.

Sliding cores *E*, Fig. 8, are used to form the inside of the cups. These cores are arranged on a plate *F* which is moved horizontally a distance of about 1 1/4 inches when the movable die is fed to the stationary die. This movement of the cores is produced by a roller attached to bellcrank lever *G*, which rides along a cam path formed by blocks on a combination bar fastened to the top of the die-casting machine.

When the movable die is withdrawn, this roller rides up the cam path, causing the bellcrank lever to swivel, and this motion, through link *H*, pulls the two slides *J* upward. Each of these slides contains two cam grooves *a* in which rollers on the sides of plate *F* travel. Consequently, as


G
H
E
J
F
E
J
G
J
a
F
a
H
E

slides *J* are raised, plate *F* is pulled back horizontally an amount equal to the throw of the cam grooves. When the movable die advances toward the stationary die, the reverse action occurs and the cores are moved forward into the cavities of the stationary die. Both dies are water-cooled when in use.

Eighteen Parts Cast at Each "Shot".—Small lead castings, approximately 5/8 inch long by 11/16 inch outside diameter, are produced at the rate of 100 per minute by the use of the dies shown in Figs. 9 and 10. Eighteen of the parts are shown beneath the dies. This number of parts is cast at each "shot" of molten lead into the dies, an average of 5 1/2 shots being made per minute. A pressure of from 225 to 250 pounds per square inch is used to force the metal into the die-cavity. A blind hole 7/16 inch in diameter extends almost the full length of the pieces.

All Excess Metal is Cut off the Parts by Means of a Slide.—One of the features of these dies is the use of a slide in the movable die to shear off all excess sprue metal from the pieces. This slide *A* is shown in Fig. 9 in the position it occupies when the face of the movable die is tight against the stationary die at the left, ready for a casting operation. At the end of an operation, the slide is gradually pushed downward while the movable die recedes from the stationary die, until it reaches the position shown in Fig. 10. During its downward movement, the slide cuts off all excess metal on the closed end of the pieces, the metal falling free of the dies.

The movements of slide *A* are obtained through a roller attached to the upper end of bellcrank lever *B* (see also Fig. 11), which engages a path formed by cam-blocks on a combination bar mounted on the top of the machine. When the movable die carriage travels away from the stationary die and carries the roller along the cam path, lever *B* is swiveled, thus moving slide *A* downward. Pilot *P* (see

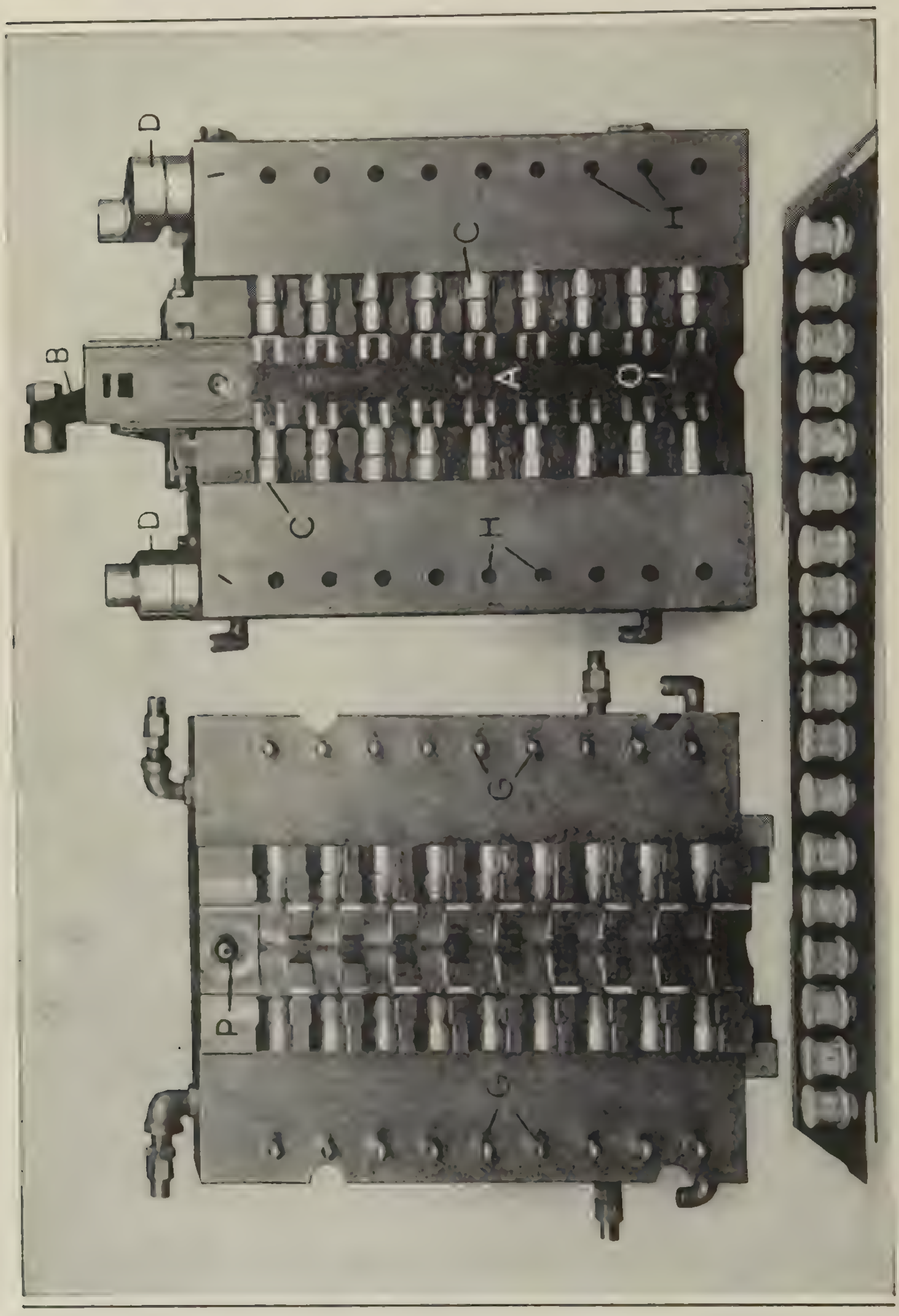


Fig. 9. A Slide in Movable Die Cuts All Sprue Metal from the Eighteen Castings when Die is Withdrawn.

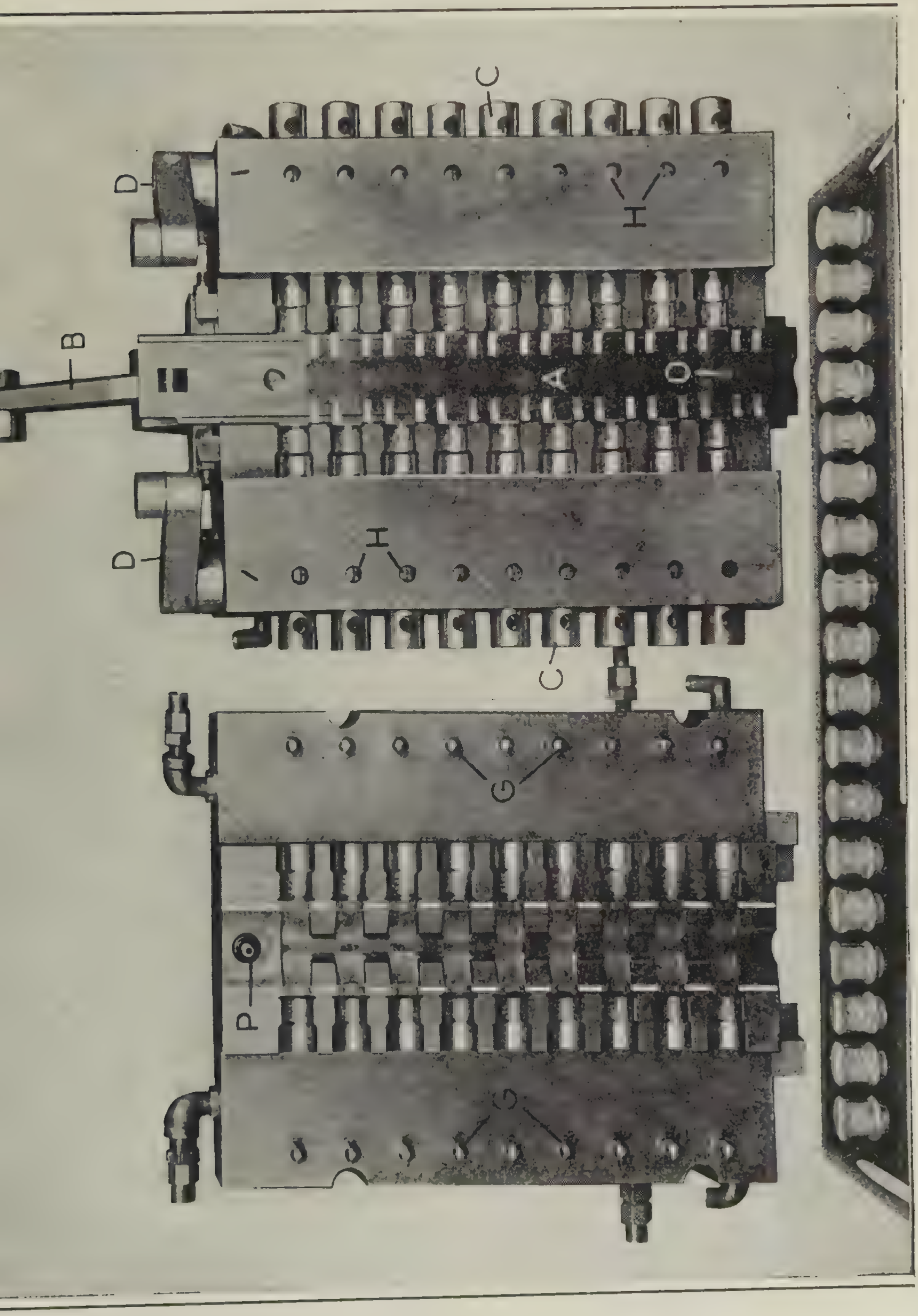


Fig. 10. Another View of the Dies in Fig. 9, Showing the Slide that Cuts off the Sprue Metal in the Lowered Position.

Figs. 9 and 10) on the stationary die enters a hole in the upper end of slide *A* when the dies are closed, so as to locate the slide accurately for the casting operation. While Figs. 9 and 10 show dies for producing eighteen pieces at once, and Fig. 11 shows the movable die of a set designed for casting twenty-four pieces at each "shot" of the die-casting machine, the mechanisms for moving the cores, the sprue-metal cutting slide, and the ejector-pins are the same in both die sets.

Operating the Eighteen Cores.—The holes in the parts are formed by means of cores *C* which may be seen in the die-cavities of the movable die in Fig. 9. They are shown in Fig. 10 withdrawn from the cavities, only the outer ends being visible. The cores are withdrawn from the castings when the movable die carriage continues its return movement after slide *A* has performed its function, motion being imparted to the core mechanisms by rollers attached to cranks *D*, which travel along cams on the under side of two more combination bars fastened to the top of the machine. These combination-bar cams cause the cranks to revolve through 140 degrees in a horizontal plane.

As cranks *D* swivel on their axes they actuate two pinions *E* (see Fig. 12) which extend the entire height of the dies. These pinions mesh with rack teeth on holders *F* to which the cores are attached. Consequently, as the pinions revolve, they withdraw all eighteen core-holders and their cores at the same time.

The reverse action, of course, takes place when the movable die carriage advances to close the movable die against the face of the stationary die. At that time the cores are pushed forward sufficiently to allow the eighteen pins *G* (see Figs. 9 and 10) on the stationary die to pass through holes *H* in the movable die and enter holes in the outer ends of the cores. (The core holes are visible in Fig. 10.) By this means the cores are accurately positioned and locked for the operation.

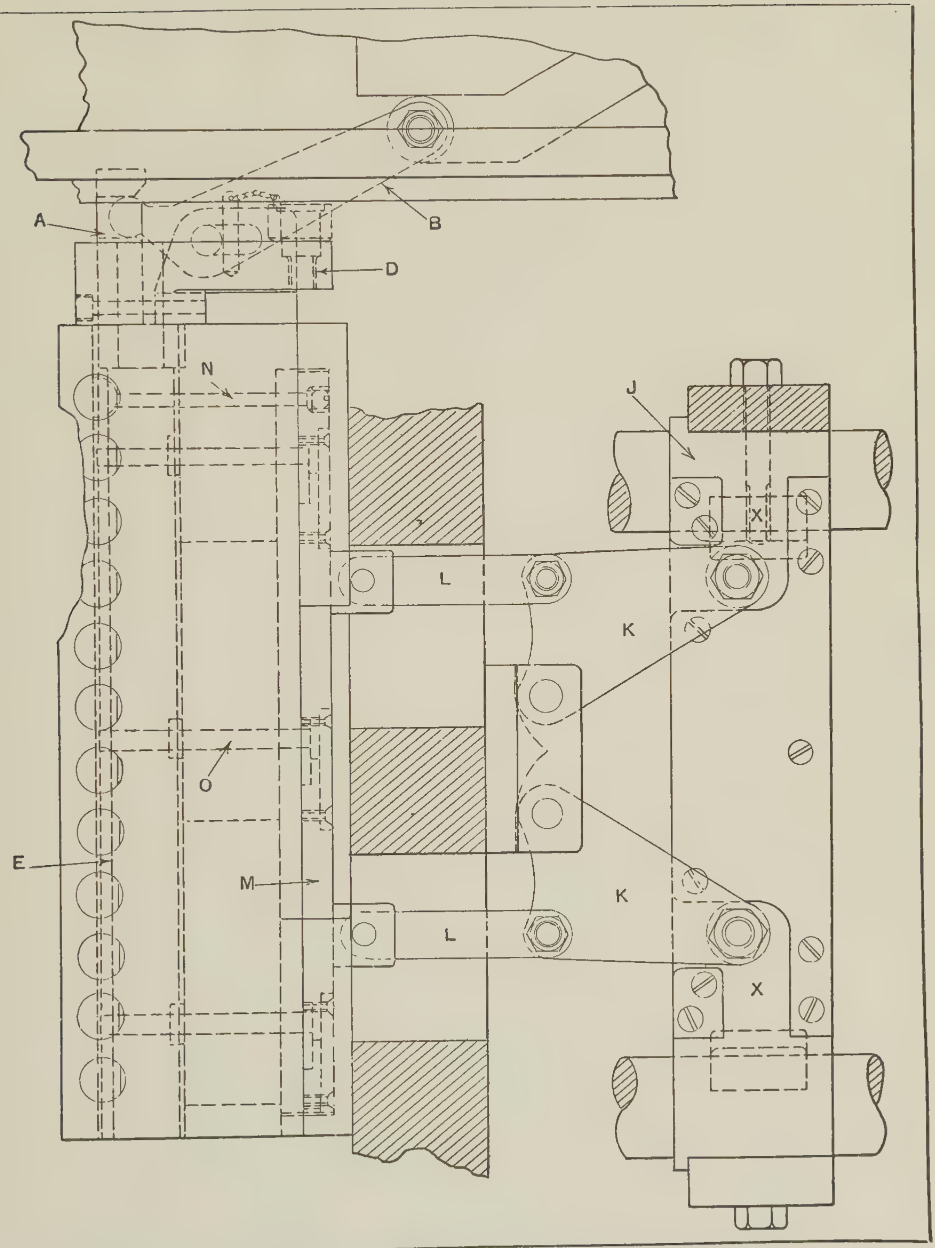


Fig. 11. Movable Die with Mechanism for Moving the Sprue-metal Cutting Slide, for Moving Twenty-four Cores Horizontally, and for Actuating Twenty-seven Ejector-pins.

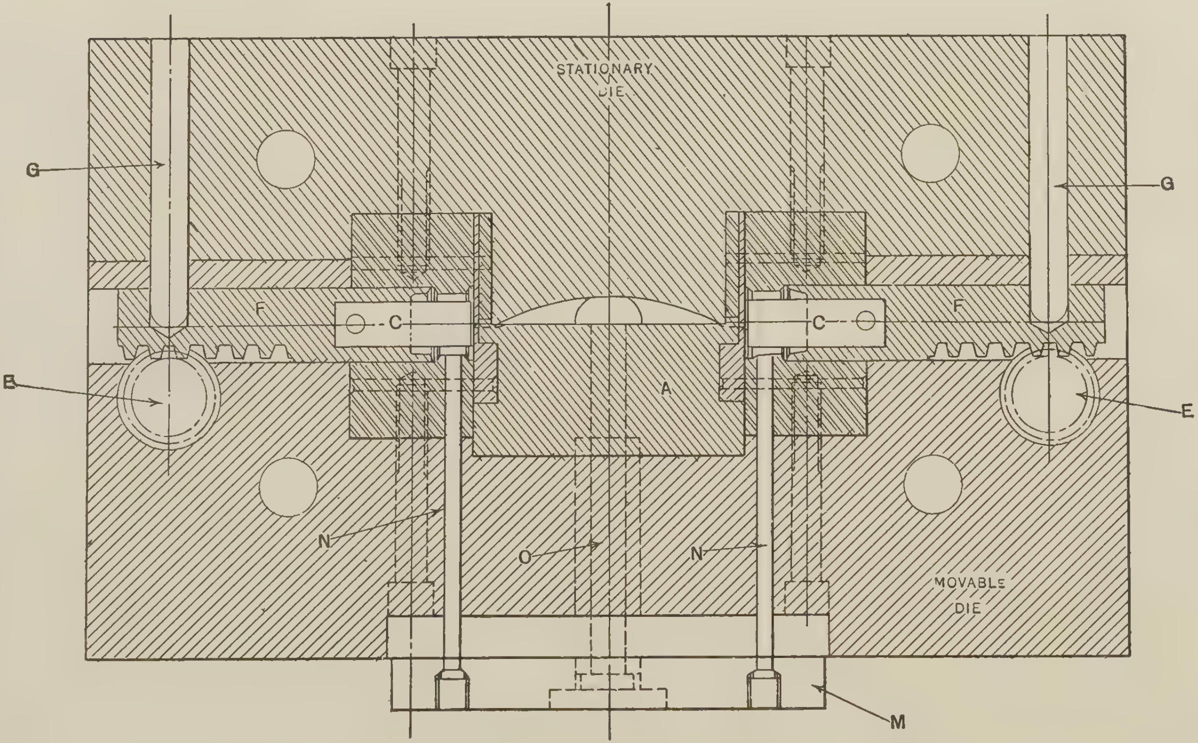


Fig. 12. Sectional View through the Movable Die Illustrated in Fig. 11. Showing the Mechanism by which the Cores are Inserted into the Die-cavities and Withdrawn from them

Ejecting the Castings.—Directly in back of the carriage, there is a vertical combination bar *J*, Fig. 11, attached to the guide bars of the die-casting machine. This combination bar actuates the ejector-pins which force the castings from the movable die where they are held securely until the cores are withdrawn.

When the carriage nears the end of its return stroke, rollers attached to the rear ends of plates *K* run along paths *X* which are formed on the combination bar by the use of cam-blocks. This movement of the rollers causes plates *K* to swing on their pivots and push rods *L* toward the left, as the die is viewed in the illustration. The opposite ends of both rods, being connected to plate *M*, push this plate forward also. Attached to plate *M* is a series of pins *N*, Fig. 12, which extend to each cavity and eject the castings as the plate is pushed forward.

Three pins *O*, attached to plate *M* at the center, eject the sprue metal which may adhere to the face of slide *A*. Since these three pins extend through slide *A* and must move vertically with it, they are held in T-slots in plate *M* rather than in round holes. While the cam-blocks that form paths *X* move the ejector-pins forward to force the castings from the die, they also provide a positive return for the ejector-pins. This is due to the fact that the rollers attached to plates *K* must travel vertically in paths *X* before they are withdrawn from the horizontal paths. Slide *A* and pins *O* can be removed from the die without taking the die from the machine. Both dies are water-cooled through the pipe connections seen in Figs. 9 and 10.

Four Different Die-Castings from One Set of Dies.—When die-castings are comparatively small and are not required in too large quantities, several different pieces can often be cast in one set of dies. The four pieces shown in Fig. 13 are produced simultaneously with each operation of the dies shown in Fig. 14. A Madison-Kipp automatic die-casting machine is used.

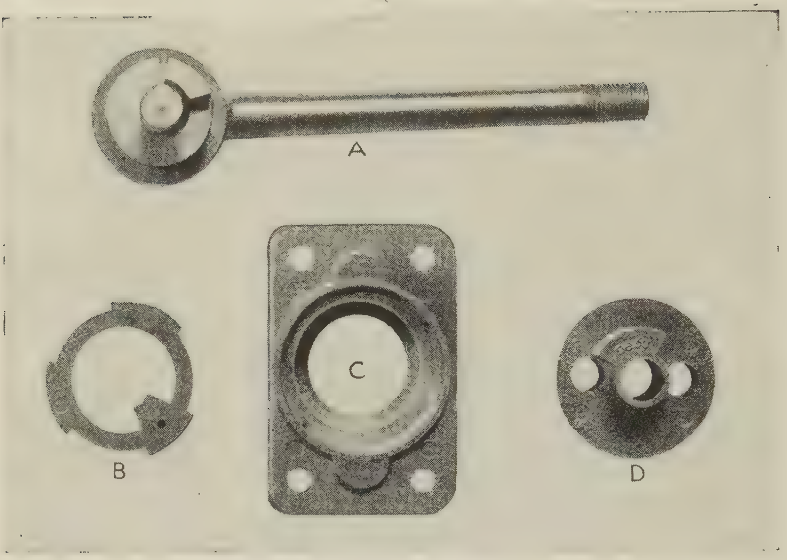


Fig. 13. Four Zinc Die-castings which are Simultaneously Cast in One Set of Dies

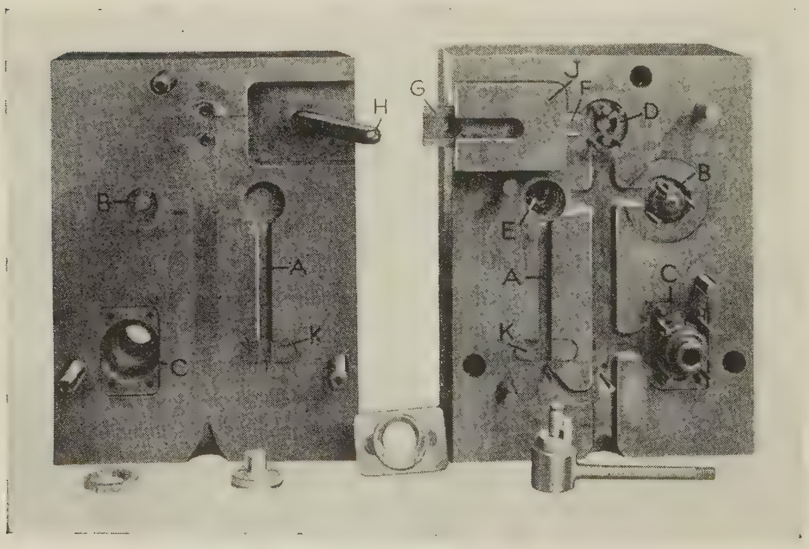


Fig. 14. Dies Designed for Simultaneously Casting the Four Different Parts Shown in Fig. 13

In Fig. 14, the stationary die appears at the left and the movable die at the right. The cavities in which the individual pieces are cast are indicated by the same reference letters that are employed to identify the pieces in Fig. 13. The gating which connects the various cavities is contained entirely in the movable die. It will be seen that metal for producing the long part *A* is shot into the cavity from both ends.

A steel spindle is cast in the hub of part *A*. This spindle is inserted in hole *E* of the movable die when the latter is withdrawn from the stationary member. Fine threads are cast on the opposite end of part *A* by means of hardened inserts *K*, which are permanently attached to both the stationary and movable dies.

Part *D* is cast with a narrow slot in one side of the central boss. This slot is produced by core *F*, which is attached to slide *G*. The core is pulled from the finished casting when the movable die is withdrawn from the stationary member. This movement of the core occurs as the hole in holder *G* slides along angle-pin *H*. Conversely, core *F* is correctly positioned by pin *H* when the dies are again closed for the next operation. Block *J* guides the sliding core-holder and fastens it to the front of the movable die.

Standard means are employed for ejecting the four pieces simultaneously from the movable die. This is accomplished by means of 15 pins attached to a plate at the back of the movable die. In Fig. 14 these pins are shown in the raised or ejecting positions. About three shots can be made a minute with these dies. The parts are cast from zinc.

Dies with Auxiliary Slides for Exterior Cores

When castings have exterior pockets or cavities which are "under-cut," the projections or cores which form them must be withdrawn to clear the casting so it can be ejected from the die. Examples of work requiring exterior pockets or under-cut parts will be shown. The dies for casting pieces of this general class are equipped with auxiliary sliding sections on the movable die which hold the projections or cores and are withdrawn to permit ejecting the casting.

Examples of Under-Cut Die-Casting which Requires Sliding Die Parts.—The motor-truck radiator ornament shown in Fig. 1 is of such a design that considerable ingenuity was required in making die-casting dies for its production. Fig. 2 shows the dies made by the Madison-Kipp Corporation for this part. The stationary die is illustrated at the left and the movable member at the right. These dies were designed for use on one of the automatic die-casting machines built by the concern mentioned.

The flat portion of the radiator ornament and a large part of the curved portion are cast in the stationary die, as will be seen from Figs. 2 and 3. However, the upper end of the curved portion is formed between sliding block *A* and moving core *B* of the movable die. Block *A* is moved upward and core *B* downward when the movable die is withdrawn from the stationary member and they are, of course, moved in the opposite directions when the dies are closed for an operation.

Both block *A* and core *B* are actuated when the handle attached to the end of shaft *C* strikes stops on the machine frame. Shaft *C* is provided with spur-gear teeth for the

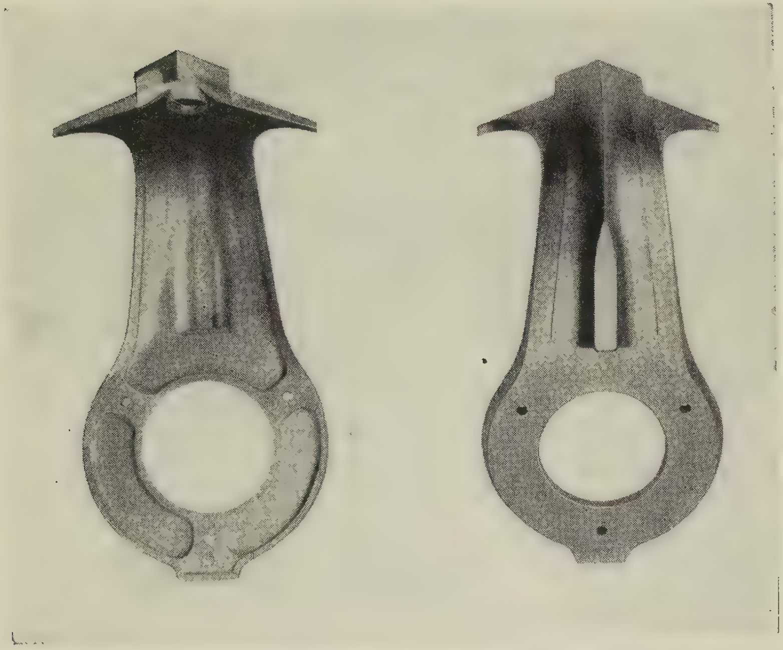


Fig. 1. Radiator Ornament of such a Design as to Require Vertically Moving Members on the Movable Die to Permit Ejecting the Casting

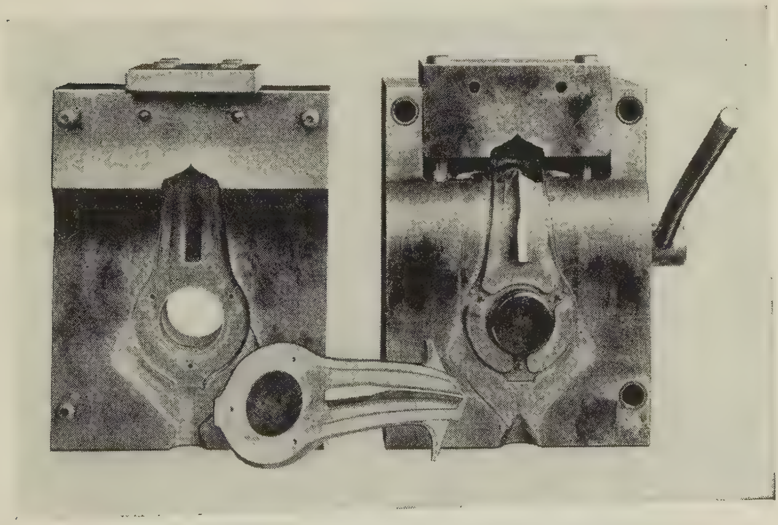


Fig. 2. Dies Designed for Producing the Radiator Ornament Shown in Fig. 1 at the Rate of 120 Castings and Hour

greater part of its length, which engage rack teeth cut on shank *D* and at two points on slide *E*. Block *A* is mounted on slide *E* and, of course, moves with it. The provision of two sets of rack teeth on slide *E* balances the power applied to it.

Block *A* is piloted up and down on the movable die by pins *F*, which also serve to hold the block to the die. It is positioned correctly with respect to the stationary die by two pins *H* which engage holes in the face of block *A*. The upper or casting position of core *B* is controlled by means of stud *J*, which engages a slot in the core.

Pins up to seven inches long are mounted on plate *L* for ejecting the finished casting from the cavity when the dies are opened, there being a total of ten ejector-pins. Two pins *K* contact with the face of the stationary die when the movable die is closed against it and push plate *L* and the ejector-pins back into the positions shown.

The radiator ornament produced by these dies is made of zinc. An average production of 120 pieces an hour can be maintained.

Intricate Die for Carburetor Casting.—The main body or central casting of a carburetor, Fig. 6, is a fine example of the point to which die-casting manufacturers have advanced in producing complicated parts. This carburetor part consists of thin sections, thick sections, cored holes at various angles, under-cuts, and other details of such a character as to tax the ability of the designer of die-casting dies.

The die used in producing this part was made by the Madison-Kipp Corporation, Madison, Wis., for use on the company's fully automatic die-casting machines.

The die for the main carburetor body opens both endwise and sidewise. It consists of two main halves, parted in line with the top face of the carburetor body (see Figs. 4 and 5). The half attached to the moving head of the die-casting machine is provided with two slides that open up sidewise. This movable die member has sliding cores which are also

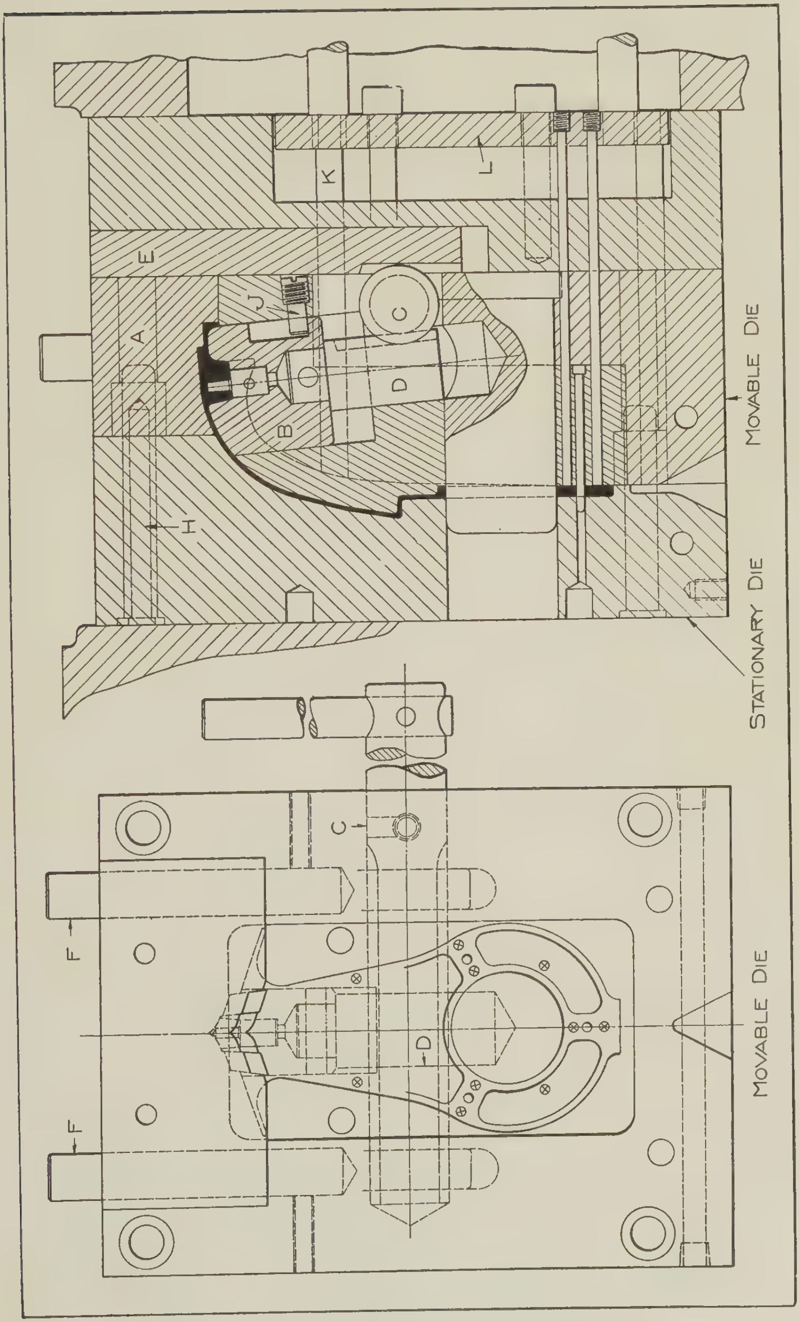


Fig. 3. Slide **A** and Core **B** of This Die Set, which Produces the Radiator Ornament Shown in Fig. 1, are Moved Vertically by Imparting a Rotary Action to Shaft C, to Clear the Casting and Permit Ejecting it

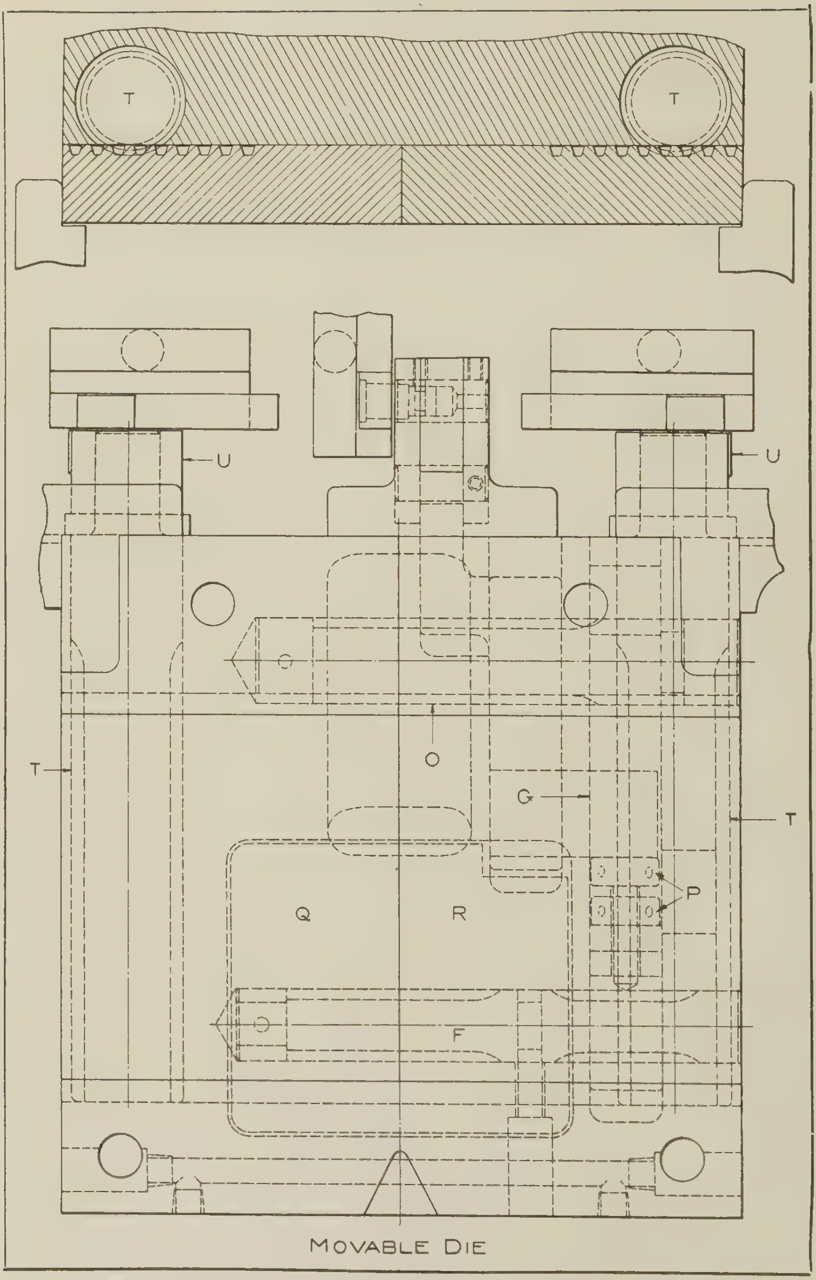


Fig. 4. Drawing of Die for Carburetor Part, Fig. 6, with Cavity Omitted to Show Mechanisms for Operating Cores and Slides

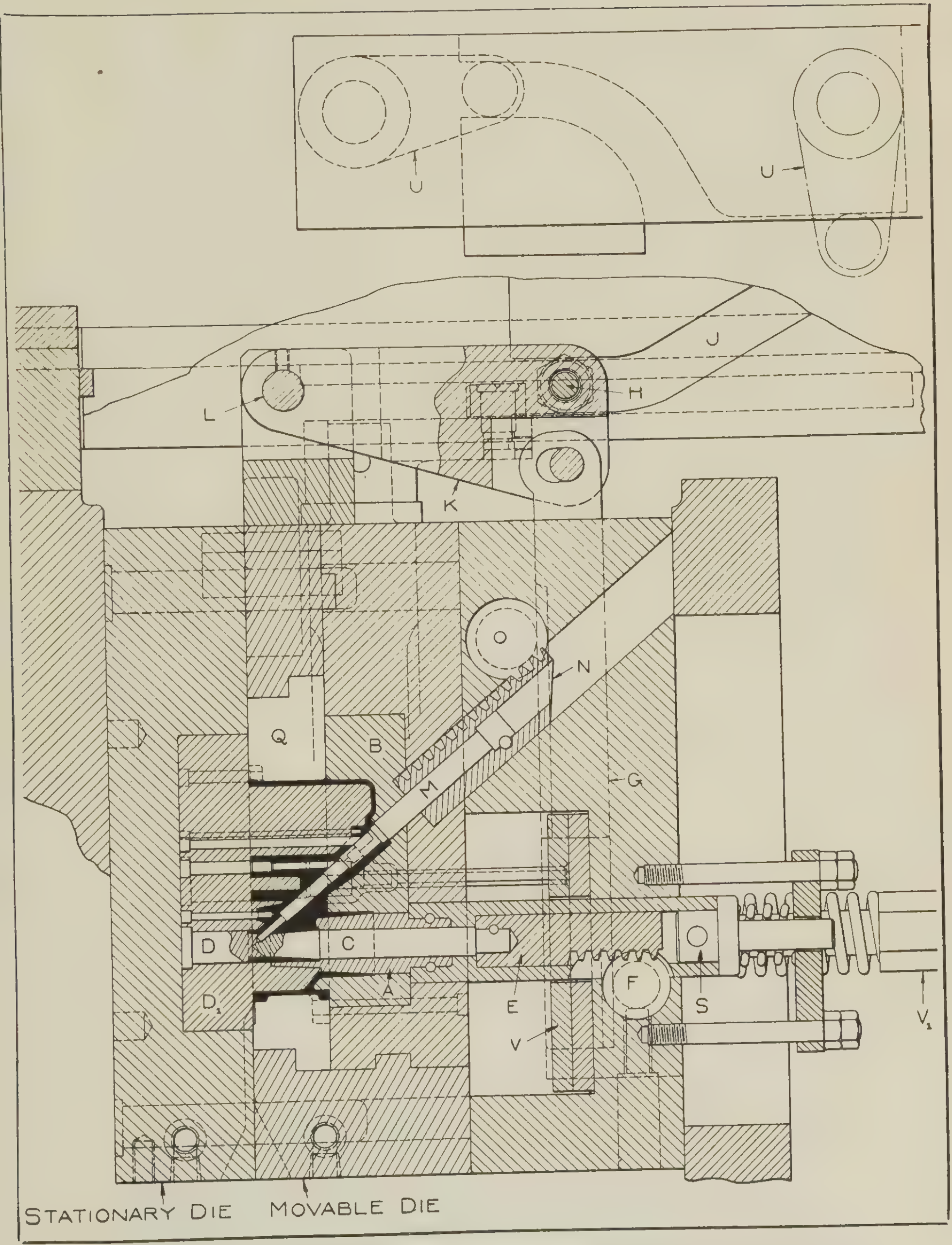


Fig. 5. Section Showing Sliding Cores and Other Moving Members of Dies that Produce Carburetor Part, Fig. 6

withdrawn from the work during the opening of the die. The details of the cavity in the movable die have been omitted in Fig. 4, so as to show the mechanisms that operate the moving cores and the two slides. Figs. 7 and 8 show this cavity, as well as the various cores on the stationary die. The stationary die is at the left and the movable die at the right.

The means for forming the cylindrical shells *W* and *X*, Fig. 6, of unusually thin section are of interest. Shells *W* are only 0.025 inch thick at the end. Each shell *W* is formed by a core *A* (Fig. 5) and a hole in die-block *B*, while each shell *X* is produced by cores *A* and *C* in the movable die and core *D* and block D_1 in the stationary member.

Core-Operating Mechanism.—All four shells must be produced straight within close limits, and hence it is necessary to withdraw each pair of cores *A* and *C* (Fig. 5) from the casting before ejecting it. The cores are withdrawn by rack *E*, which engages pinion shaft *F*. Core *C* is withdrawn first from the casting, core *A* remaining stationary until the rack strikes stop *S*. Then cores *A* and *C* are withdrawn together as rack *E* completes its movement.

Pinion shaft *F*, which also engages rack *G*, is revolved as this rack is pulled upward during the withdrawal of the movable die at the end of an operation. During this die movement, a roller on shaft *H* advances along cam path *J*, which is formed by means of blocks on the vertical face of a bar mounted on top of the machine. This roller is attached to plate *K* which pivots on pin *L*. The upper end of rack *G* is also fastened to plate *K*, so that the vertical movement of the roller on shaft *H* causes a corresponding movement of rack *G*.

Cores for Holes in Angular Position.—Three sliding cores are required to produce holes *Y*, Fig. 6. Two of these holes are approximately 2 7/8 inches long and decrease in several steps from a diameter of 3/8 inch at the top to 1/8

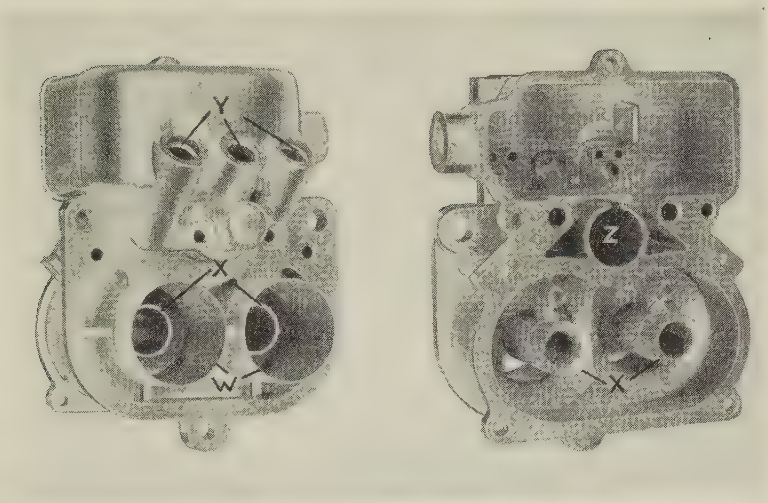


Fig. 6. Carburetor Part of Intricate Design Illustrating Present Possibilities of Die-casting Process

inch at the point where they intersect holes *X*. The central hole *Y* is only about 7/8 inch long, because it is intersected by hole *Z*. The two outside holes *Y* are produced by long cores of the design shown at *M*, Fig. 5.

All three cores for holes *Y* are attached to holders of the type shown at *N*. These holders have rack teeth on one side which engage pinion shaft *O*. Shaft *O* is also actuated by rack *G* when that rack is moved upward, as already described. Rack *G*, therefore, operates seven cores.

Flash is eliminated at the points where the two holes formed by cores *M* intersect with the larger holes *X* (see Fig. 6) by extending the slender end of cores *M* into the angular faces of cores *C* and *D*. This eliminates a trimming operation on the casting, and also holds cores *M* in position to maintain a very close tolerance. Nuts *P*, Fig. 4, provide adjustment so that the different cores are operated in synchronism. In addition to the moving cores, there are a number of fixed cores on the stationary and movable dies.

Cores for Outside Pockets.—Pockets in the outside surfaces of the casting are formed by cores fixed to sliding members Q and R of the movable die (Fig. 8). Half of the die-cavity is formed in each slide Q and R. These slides join on the vertical center line of the part for the casting operation and are opened up for ejecting the casting during the withdrawal of the movable die as pinion shafts T, Fig. 4, turn on their axes. These pinions engage rack teeth cut on the back of each slide. Pinion shafts T are rotated as the rollers attached to crank-arms U follow cam paths in the horizontal faces of bars located on both sides of the machine above the dies. These crank-arms are swung through approximately 100 degrees to move each slide about 1 1/2 inches. In Fig. 7, the movable die is shown with the two slides and the various moving cores in the casting position, while in Fig. 8 it is illustrated with the slides and cores withdrawn to the ejecting position. Guide bars on the stationary die insure proper closing of the slides when the movable die is against the face of the stationary member.

Ejecting Carburetor Casting.—As the movable die approaches the end of its withdrawal stroke, the casting is ejected by four long slender pins attached to plate V, Fig. 5. These pins extend through the die parts to the bottom of the cavity. Plate V is fastened to two studs V_1 which extend to the right of the movable die unit and contact with a bar so as to stop the movement of plate V as the die approaches the end of its stroke. Thus, the ejecting-pins are pushed into the die-cavity and eject the casting while the movable die completes its opening stroke.

When the movable die is again closed against the stationary member, the coil springs that surround studs V_1 force plate V into its normal position, thus drawing the ejecting-pins flush with the surface of the die-cavity. Ejector-pins are not required on the stationary member.

Close tolerances are adhered to, so as to hold the leakage of air and the clearance between operating parts to the minimum. The gating that insures the delivery of molten

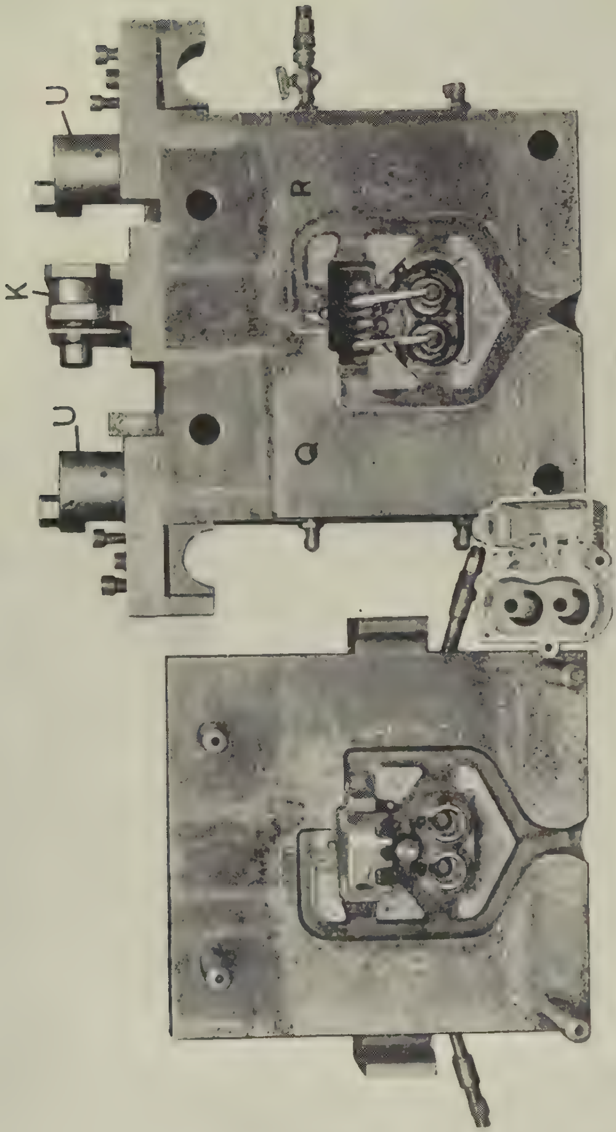


Fig. 7. Dies for Carburetor Die-casting. Stationary Die Shown at Left and Movable Die at Right in Closed Position

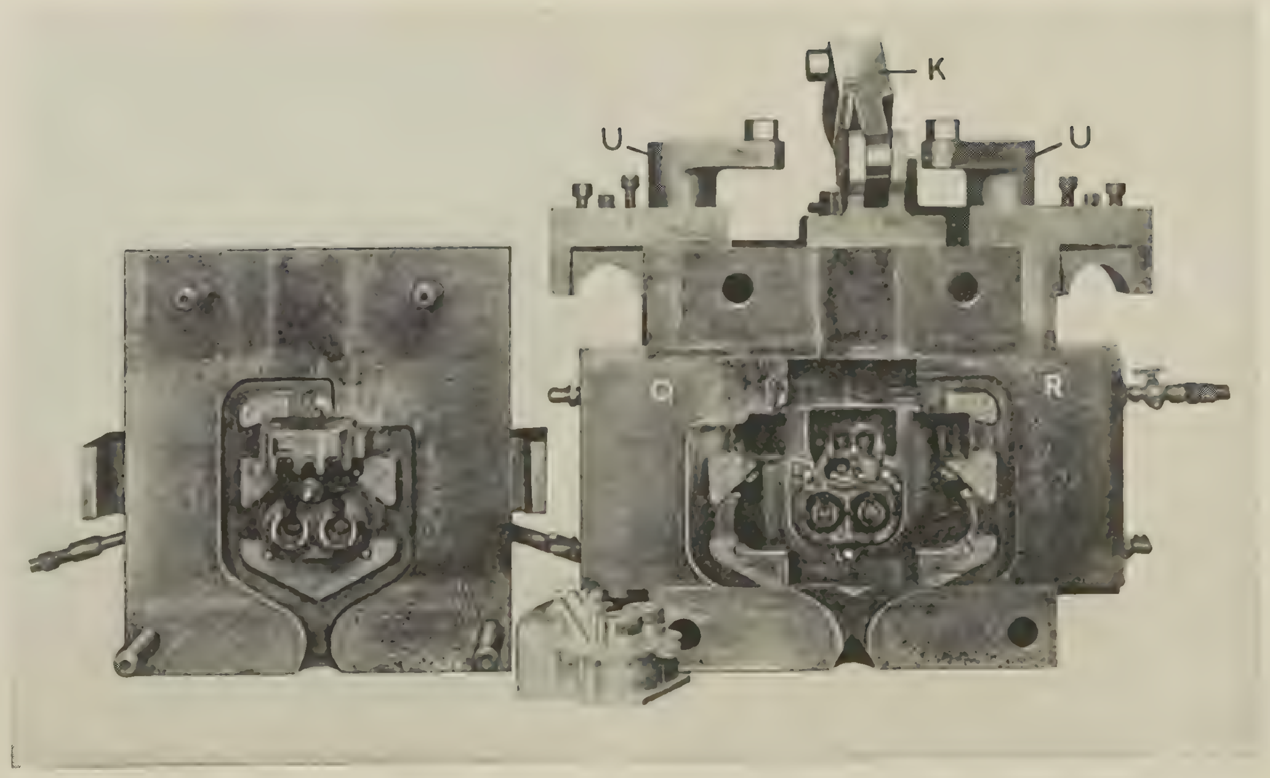


Fig. 8. Carburetor Main-body Die Set with the Various Sliding Members of Movable Die in Open or Ejecting Position

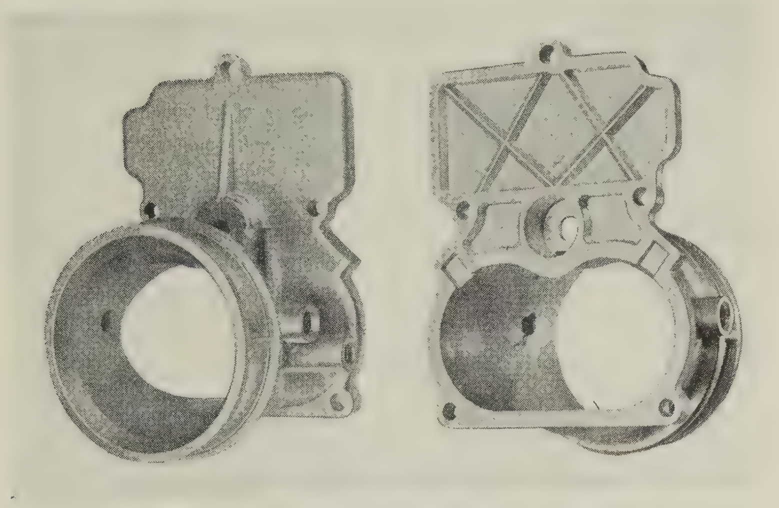


Fig. 9. Two Views of the Air Horn or Upper Body of an Automobile Carburetor Produced in the Dies Shown in Figs. 10 and 11

metal to all parts of the die can be seen in Fig. 7. A uniform temperature of the various die members is obtained by circulating cooling water through both slides of the movable die and across the bottom of both the stationary and movable die members in the vicinity of the sprue.

This carburetor casting is made of zinc at a casting temperature of about 825 degrees F. Approximately 180 castings can be produced an hour. The castings are 3 3/8 by 4 1/2 by 2 1/2 inches over-all. The dies will last, with proper upkeep of the sliding parts, for hundreds of thousands of castings.

Dies for Air Horn of Carburetor.—Two views of the air horn or upper body of a carburetor are shown in Fig. 9. The die set for this part is also constructed with a movable member that opens up endwise relative to a stationary member and has slides that move sidewise on the movable member to permit the formation of ribs and under-cuts on the casting.

One of the interesting features of these dies is the use of a pin *A* on the stationary die (see Figs. 10 and 14) to operate sliding part *B* of the movable die. This part forms a flat surface and also cores a narrow slot in the wall of the carburetor. Part *B* must be moved vertically to permit ejecting the finished casting. It is attached to holder *C* for this purpose. Pin *A* is mounted at an angle on the stationary die; consequently, when the movable die is withdrawn from the stationary member, holder *C* is compelled to slide up along pin *A* and this moves part *B* vertically from the die-cavity a distance of about 5/8 inch. Part *B* is dovetailed to block *D* to prevent it from falling off the face of the die and it is held in the raised position by spring detent *E*. Core *F* in Fig. 13 produces a small hole at one side of the casting center. This core must also be withdrawn from the casting and it is mounted in part *B* for that purpose. One side of the boss that surrounds the hole produced by core *F* is formed by part *B*, while the remainder of the boss receives its shape from the left-hand slide of the movable die.

The inside of this carburetor casting is formed by core *G* (Fig. 14) on the movable die, and block *H* on the stationary die. Block *H* is machined with two projections that fit closely over a square tongue on the end of core *G*. The construction of these two parts will be understood from the detailed drawings, Fig. 12.

Water-Cooled Core.—Core *G* would become excessively hot and result in die-castings with blistered inside surfaces if provisions were not made to keep down its temperature. Therefore, the core was made with a quill *J*, Fig. 14, 5/16 inch outside diameter, which extends almost the full length of the core in a 3/4-inch hole. Water is forced continually through the quill and it returns from the die through the hole in which the quill is placed.

With this arrangement, core *G* is maintained at the same temperature as the other parts that form the die-cavity.

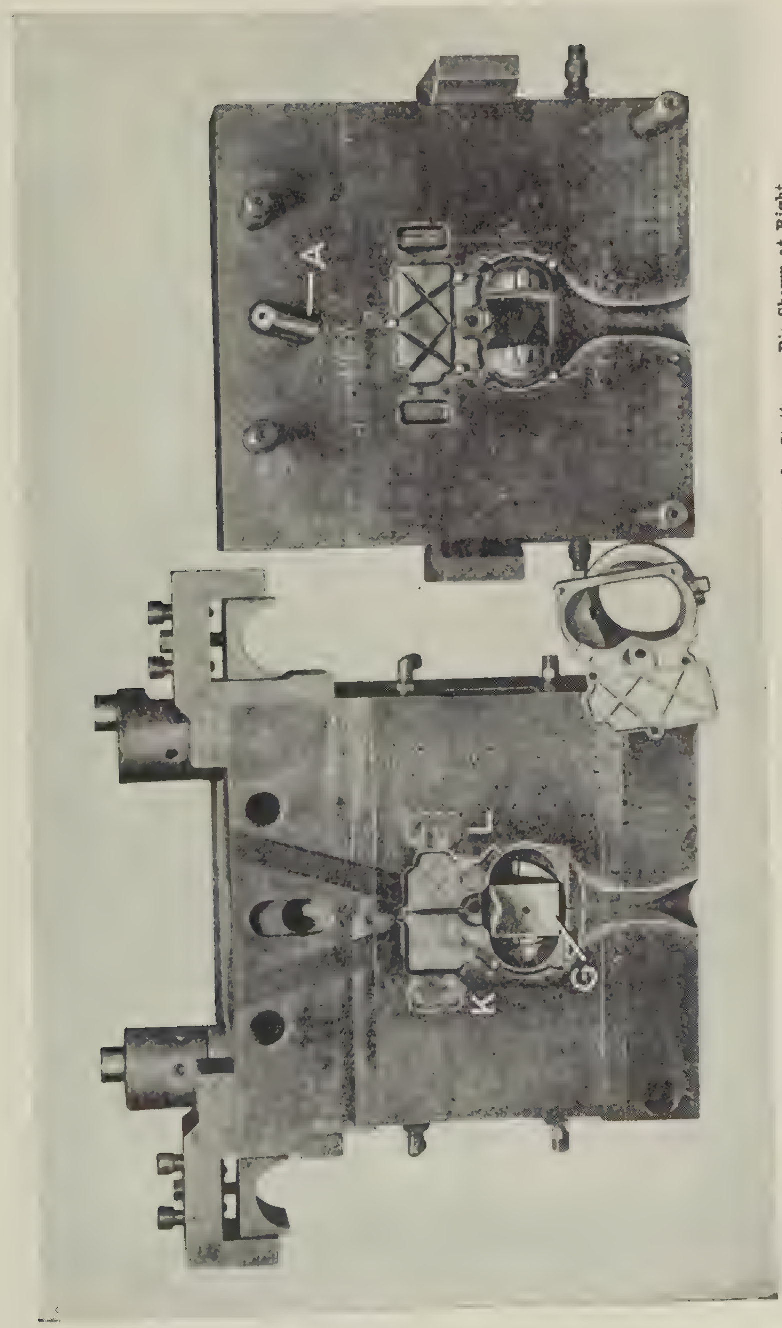


Fig. 10. Die Set Used for Producing the Carburetor Casting Shown in Fig. 9. Stationary Die Shown at Right and Movable Die at Left in Closed Position

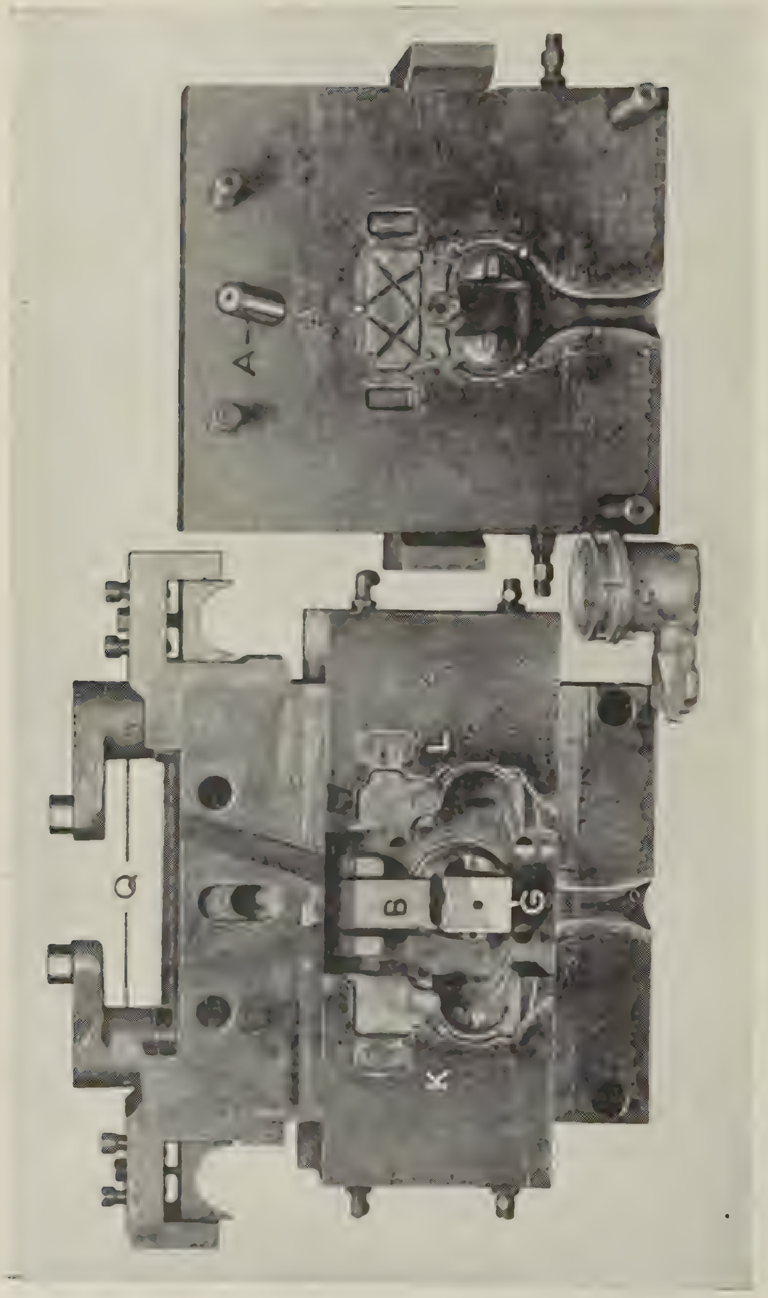


Fig. 11. Another View of Carburetor Air-horn Die-casting Dies which Shows the Various Sliding Members of the Movable Die in Open or Ejecting Position

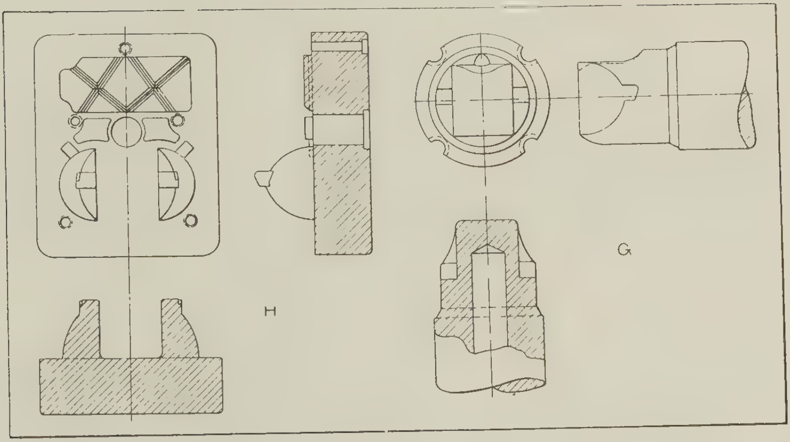


Fig. 12. Details of Die-block Insert H and Core G (See Fig. 14) which Form the Inside of the Carburetor Air-horn Die-casting

Water is also circulated across the bottom of both the movable and stationary dies in the vicinity of the sprue, as well as in slides *K* and *L* of the movable die which form the sides of the casting.

An Ejector Sleeve Used Instead of Pins.—Most automatic die-casting dies made by the Madison-Kipp Corporation are provided with long slender pins for ejecting the casting from the movable die. In the case of the dies here described, pins were not feasible. Ejection is accomplished by means of the long steel sleeve *M*, Fig. 14, which also serves to close one end of the die-cavity. When the movable die is withdrawn from the stationary member at the end of a casting operation, sleeve *M* is withdrawn with the other parts until the head of stud *N* strikes a stop on the machine. Then plates *O*, and, of course, sleeve *M* are prevented from moving farther, and as the movable die continues to the end of its stroke, the casting is forced from the cavity by sleeve *M*. The sleeve is returned to its normal position by the spring that surrounds stud *N* when the die is closed for the next operation.

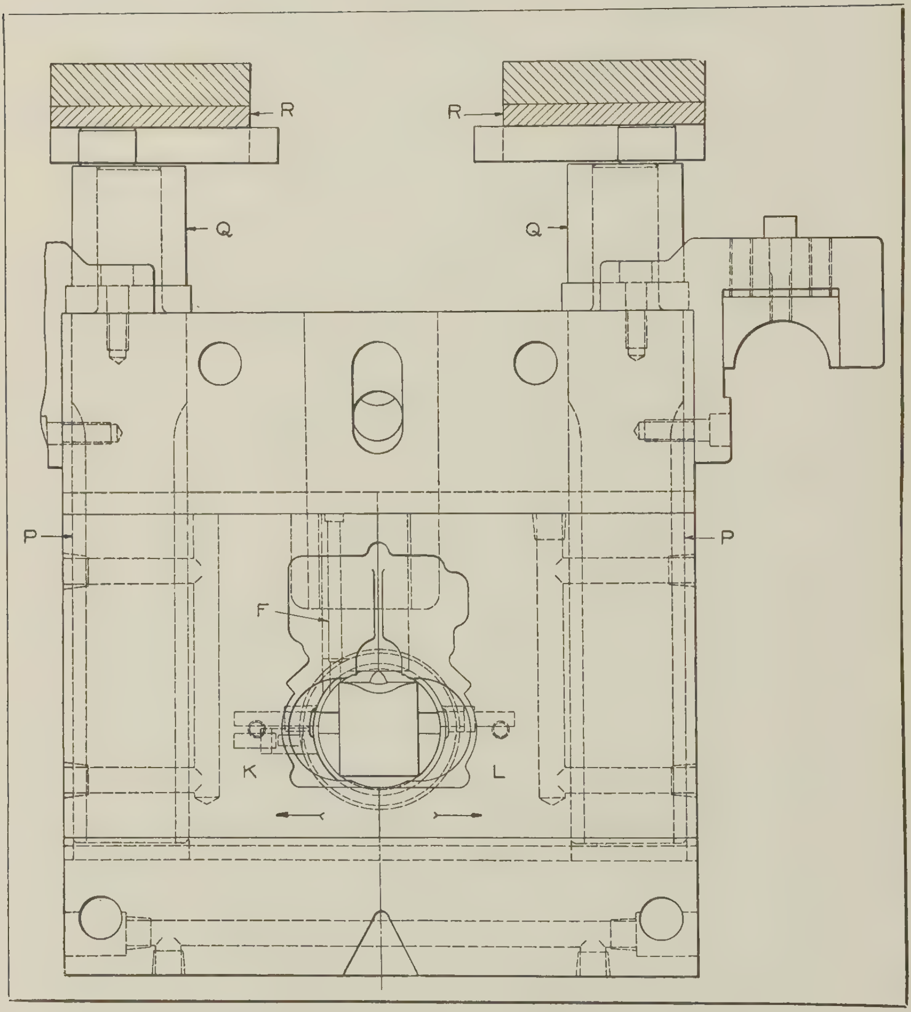


Fig. 13. Drawing of Movable Die Shown in Figs. 10 and 11. See also Fig. 14

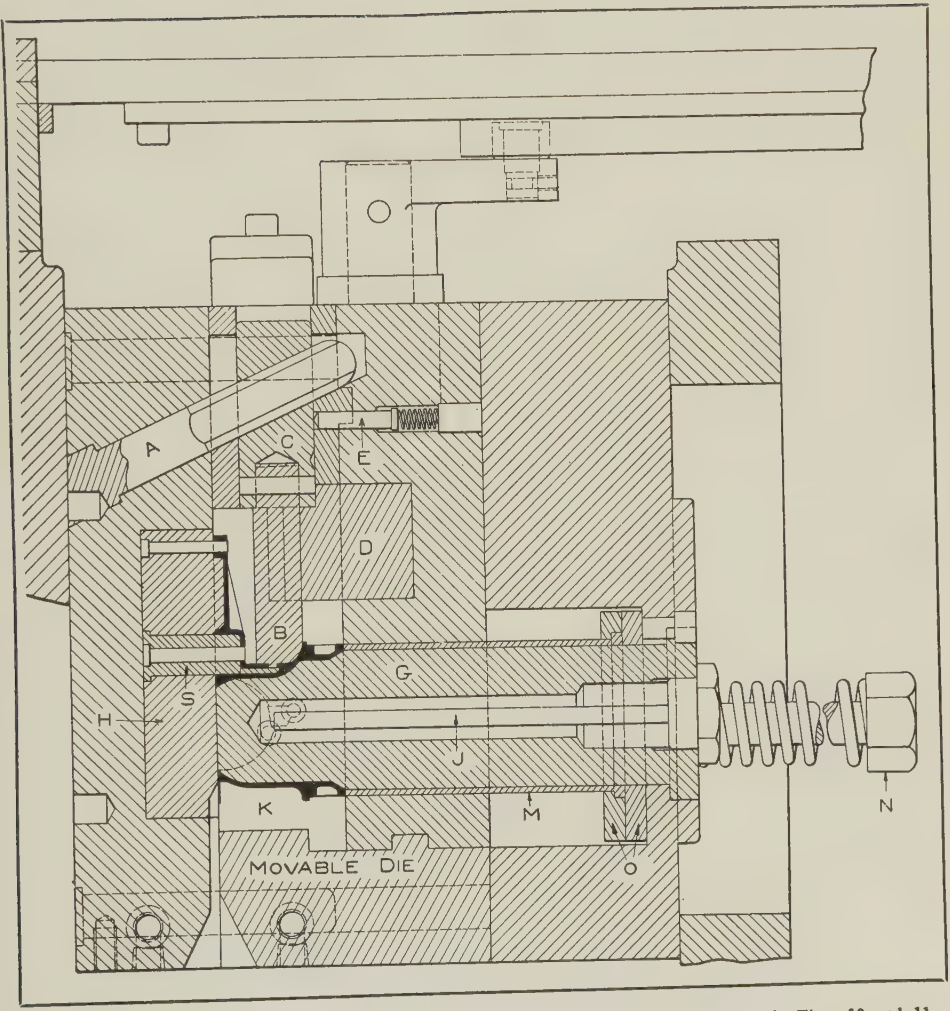


Fig. 14. Section Showing Method of Operating the Moving Members of Dies Shown in Figs. 10 and 11

Operation of Auxiliary Slides.—The opening and closing of slides *K* and *L*, Fig. 13, are effected similarly to the movement of the slides on the die for the main carburetor body, which was previously described (see Figs. 4 and 5). Slides *K* and *L* are operated sidewise by two pinion shafts *P*, which engage rack teeth cut in the back of the slides. At the upper end of each pinion shaft is mounted a crank-arm *Q*, which carries a roller that engages a cam groove in a bar *R* extending along the top of the machine. These pinion shafts are swiveled approximately 100 degrees as the rollers of the crank-arms follow the cam paths in bars *R*. Each slide is opened a distance of 1 1/2 inches.

Slides *K* and *L* are provided with several cores that produce holes horizontally in the casting. The slides are shaped to give the entire external contour of the casting, with the exception of the ends and the narrow surface that is formed by part *B*. Guide bars mounted on the stationary die insure proper closing of the slides for casting.

Attention is called to the long narrow slot that is formed by a slender projection on core *S*, Fig. 14. This projection extends into the die-cavity to form a hole that intersects the slot produced by core *B*. The projecting finger of core *S* is only 7/64 inch thick by 3/8 inch wide by 11/16 inch long. The stationary die member *H* is provided with six fixed cores for producing a similar number of holes, and, in addition, this die member is shaped to produce the under side of the casting, as seen in the right-hand view of Fig. 9.

The gating provided for this set of dies can be observed in Figs. 10 and 11. At the point where the molten metal enters the die-cavity, the gate is 1/32 inch deep and about 2 3/4 inches wide. About six "shots" can be made per minute with these dies. The castings are made of zinc. The dies will last for hundreds of thousands of castings.

Sliding Cores in Movable and Stationary Dies

Forming the interior cavities in some castings requires the use of sliding cores in each die section. Some examples of dies of this general type will be described. The exact arrangement of the cores and method of operating them must, of course, depend upon the shape of the casting and relative locations of the cavities and cores which form them, but the examples which follow will suggest practical core arrangements for other forms of castings.

Sliding Cores in Both Movable and Stationary Dies.—Dies designed for casting the speedometer brackets (two at a time) illustrated in Figs. 1 and 2 are shown in Figs. 3 and 4, the stationary die being at the right in each illustration. Both die members are equipped with moving cores. In Fig. 3 the dies are shown with the moving cores in the positions they occupy when the dies are closed for the casting operation, while Fig. 4 shows the dies with the moving cores withdrawn. Three "shots" are made or six parts cast per minute with this die equipment. The parts are approximately 2 3/4 inches in diameter and are made of zinc.

One of the features of the movable die is the use of four sliding die-blocks for forming the threads of nipples *A*, Figs. 1 and 2. These blocks, which are shown at *F*, in Figs. 3, 4, and 5, must be moved apart to release the casting when the dies are opened, and they must be slid together before the dies are closed preceding an operation. Movement of the blocks is effected through three slides *G*, *H*,

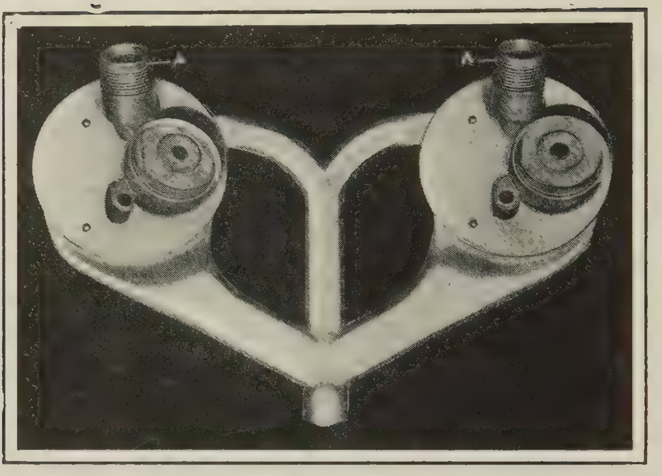


Fig. 1. Two Zinc Speedometer Brackets Cast at One Time

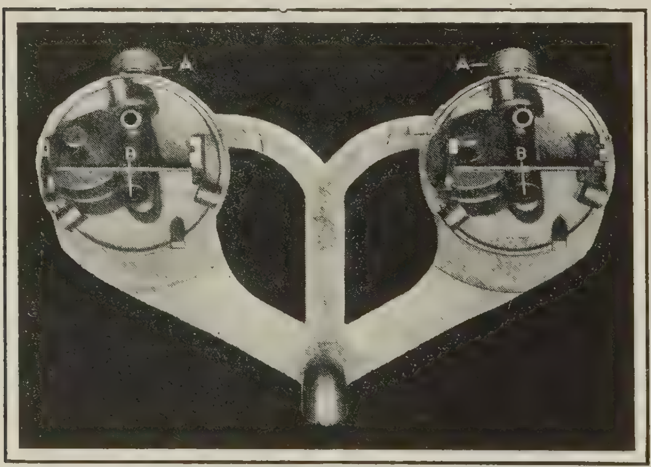


Fig. 2. Reverse View of Casting Illustrated in Fig. 1

and *J*, which have rollers at the top that engage the cam-blocks fastened to two combination bars at the top of the machine. Slides *G*, *H*, and *J* are pulled upward when the dies are opened and lowered as they are closed.

Rollers such as shown at *K*, Fig. 5, are fastened to the back of each die-block *F*. These rollers engage cam grooves

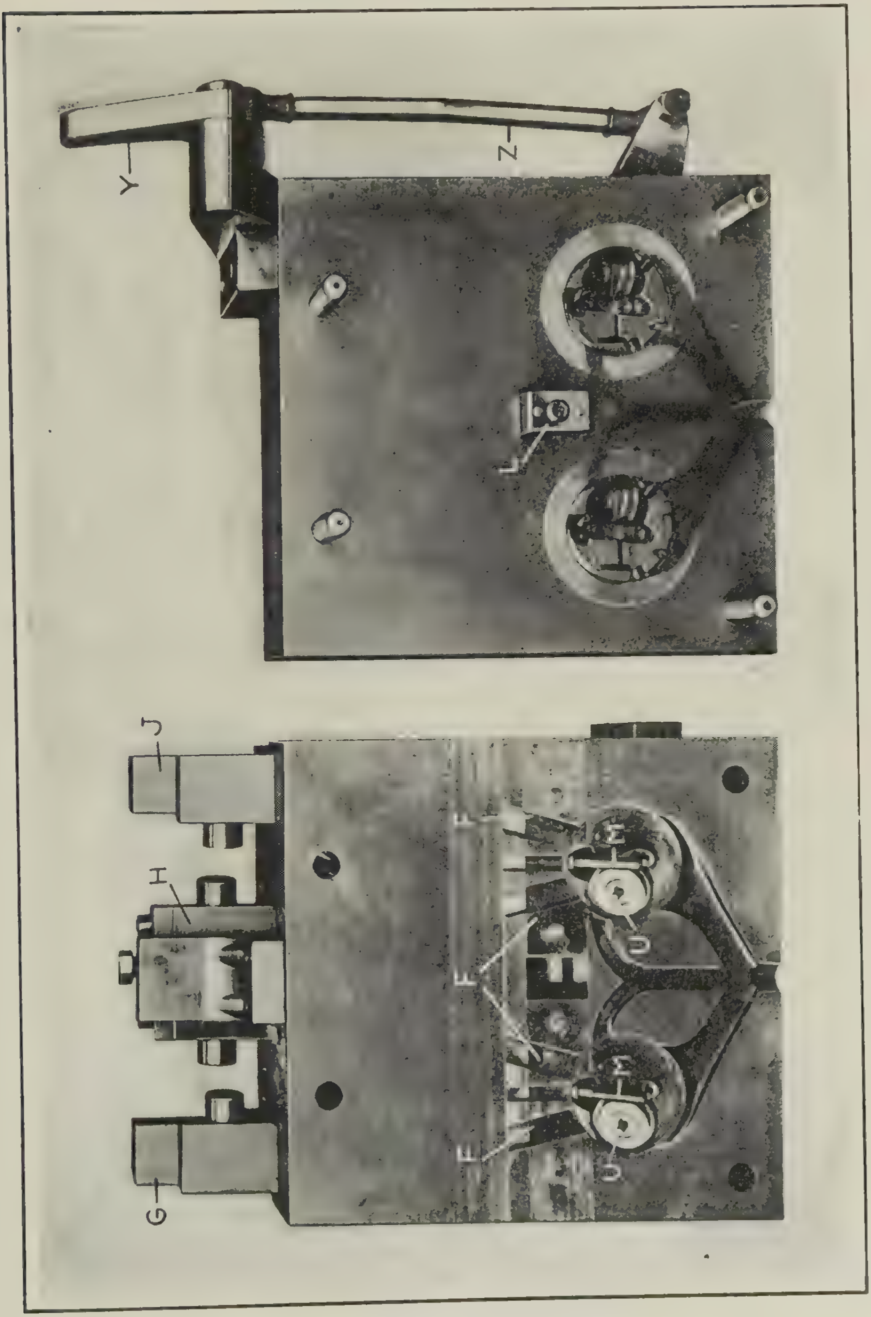


Fig. 3. Speedometer Bracket Dies in which both the Movable Die at the Left and the Stationary Die at the Right are Provided with Sliding Cores and Thread-blocks

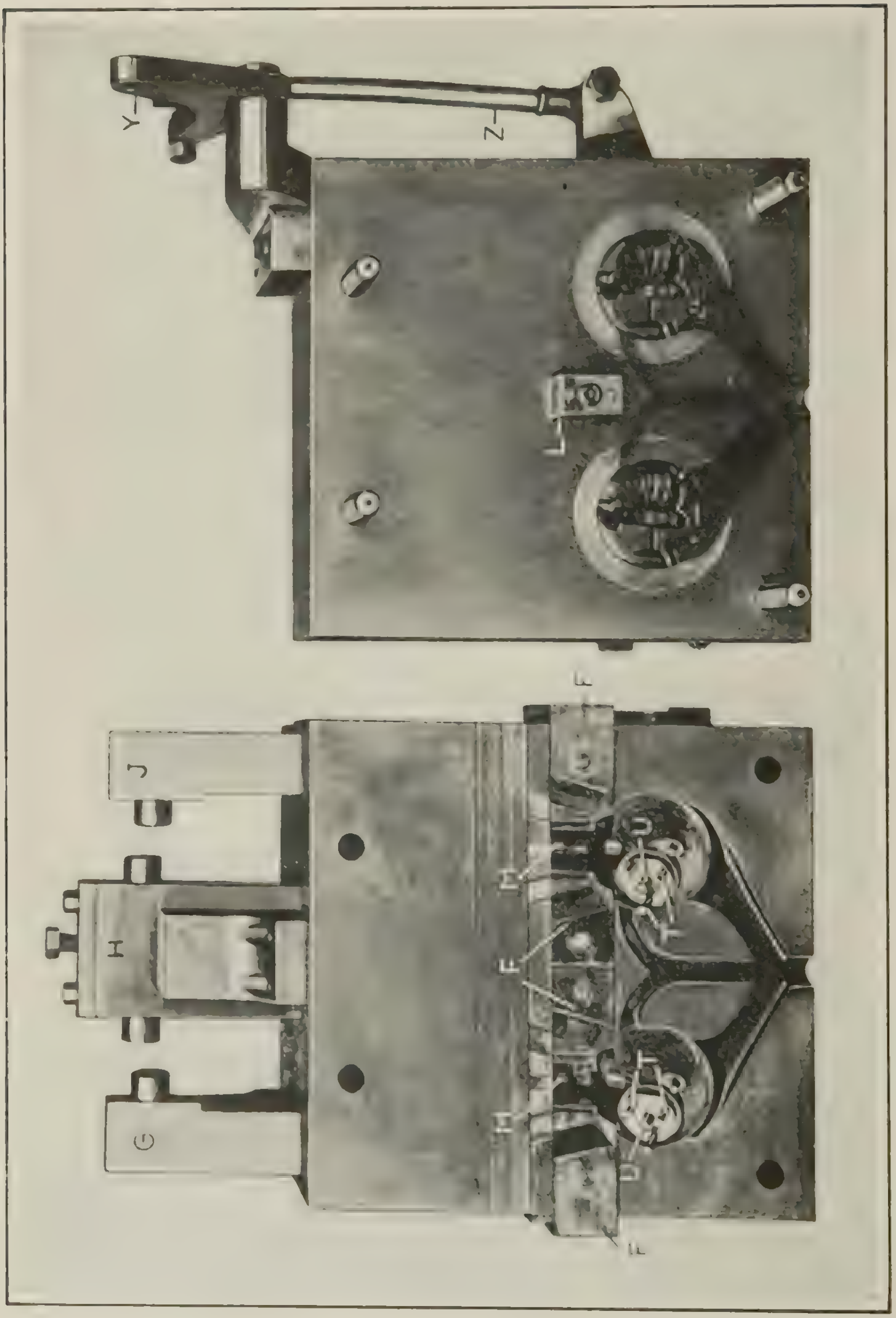


Fig. 4. Another View of the Speedometer Bracket Dies, with the Cores and Thread-blocks Withdrawn and the Ejector-pins Advanced

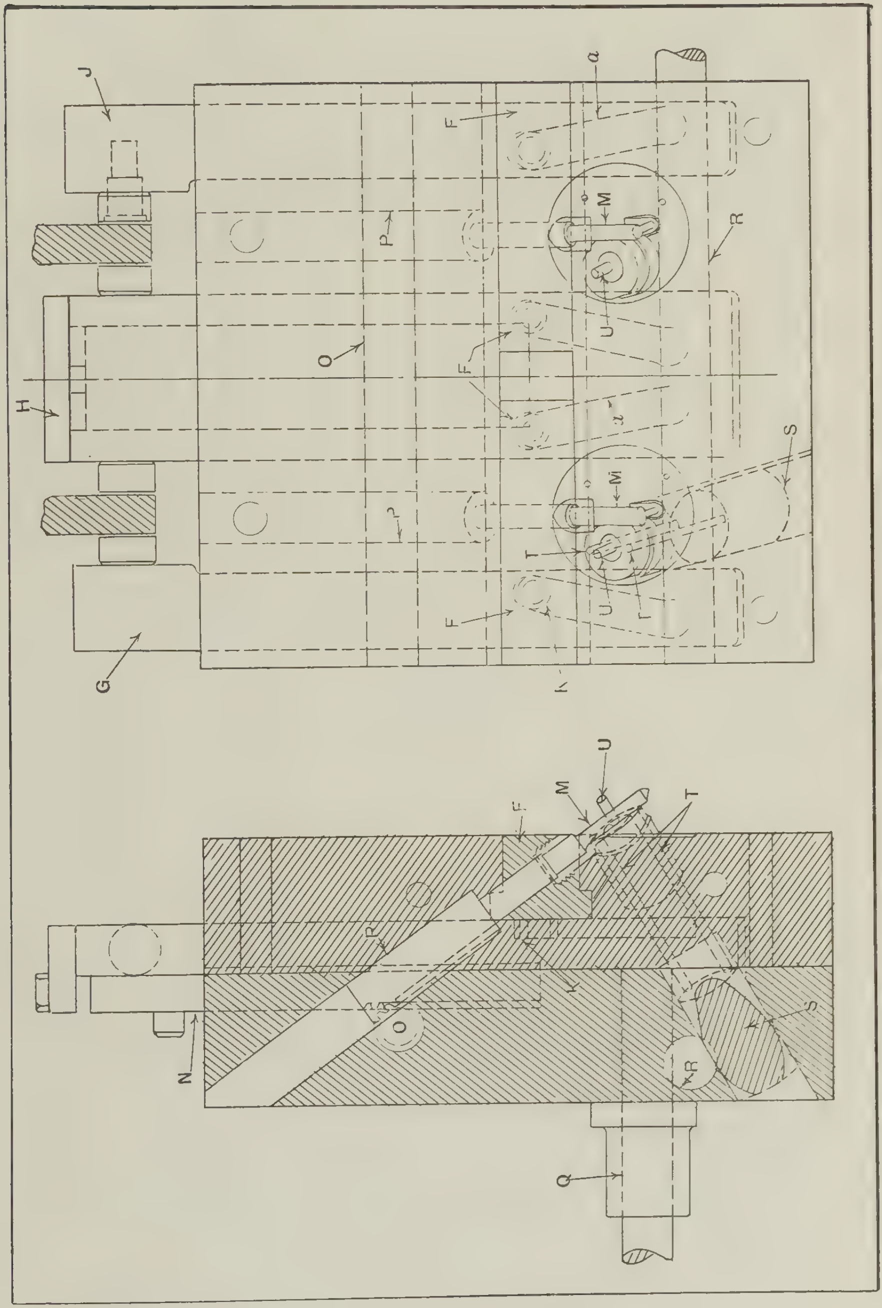


Fig. 5. Construction Drawing of Speedometer Bracket Movable Die, Showing Means Employed for Moving Sliding Thread-blocks, Long Slender Cores, and Ejector-pins

of the type indicated by dotted lines *a* which are machined in the three slides. Thus, as the slides are pulled upward when the movable die is withdrawn, the cam grooves force the die-blocks sideways as required. Conversely, when slides *G*, *H*, and *J* move downward in closing the dies, the blocks are pushed together firmly until the square plug *L*, Figs. 3 and 4, of the stationary die, can enter between the middle two blocks *F*.

Rack-and-Pinion Mechanisms Move Long Slender Cores.— Cores *M*, Figs. 3, 4, and 5, form the holes *B*, Fig. 2, which extend from the top of nipples *A*. The holes are 9/16 inch diameter in the nipples and 9/32 inch for the remaining length. The total length of the holes is 2 5/16 inches, and the cores used for producing them are moved that amount. This movement of the cores is effected through a rack *N* which is fastened to the back of slide *H*. The rack engages pinion teeth cut on shaft *O* which extends the full width of the die. Directly above each die-cavity this pinion engages rack teeth cut in a sleeve *P* to which the corresponding core *M* is attached. Thus, as slide *H* moves upward to open the middle two blocks *F*, it also withdraws cores *M*, and when the slide moves downward to close blocks *F*, cores *M* are lowered into place.

Casting Ejected at an Angle from the Horizontal.— Near the bottom of the movable die there is a rack *Q*, Fig. 5, which is actuated lengthwise by a lever attached to a special bracket on the movable die carriage, operated from one of the combination bars at the top of the machine as the carriage is moved back and forth. When this rack is pulled backward, it revolves a pinion shaft in hole *R*, the teeth of which engage rack teeth cut on two holders *S*, only one of which is shown in the front view of the illustration. Ejector-pins *T* fastened to holders *S* are thus pushed forward with their holders to force the casting from the movable die as it recedes from the stationary die.

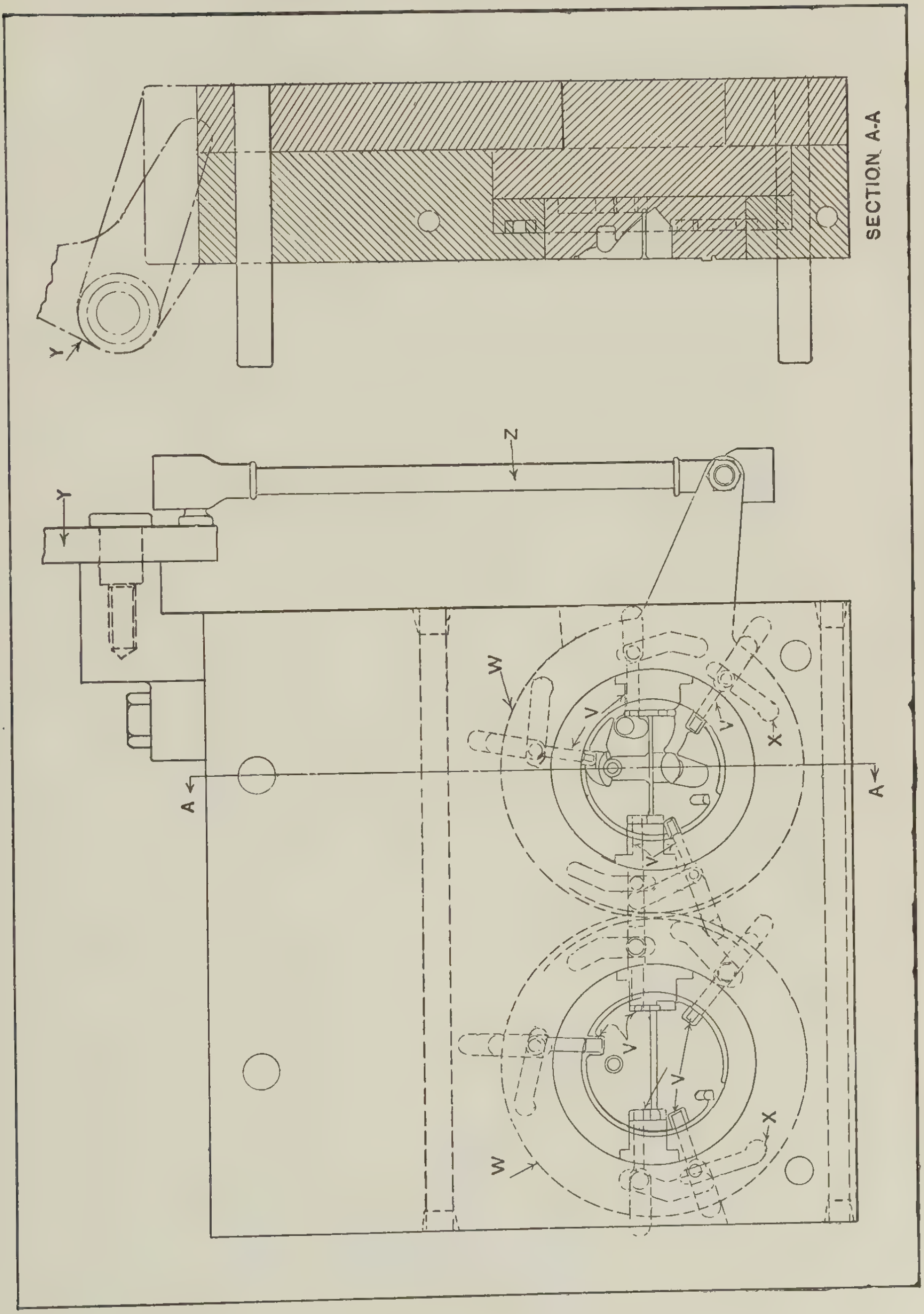


Fig. 6. Details of Speedometer Bracket Stationary Die, Illustrating the Use of Rotating Plates with Cam Grooves for Moving a Series of Cores in Different Directions

When this die was originally designed, the intention was to provide only two of these ejector-pins for each holder, as shown, but as finally built, three ejector-pins were provided for each holder, as shown at *T* in Fig. 4. When the movable die is moved into contact with the stationary member, the same mechanism acts to withdraw the ejector-pins as shown in Fig. 3. Core-pins *U* are stationary.

From observation of Figs. 3 and 4 it will be seen that the sprue passages are contained entirely in the movable die. The operating line of the casting coincides with one side of the sprue web. Plug *L* effectively prevents any metal from entering between slides *F* as the "shots" are made.

Sliding Cores of the Stationary Die.—Five holes are formed in the rim of each speedometer bracket through the use of sliding cores *V*, Fig. 6. These cores slide in five different directions but all in one vertical plane, so that they can be readily actuated through the use of plates *W* which have cam slots *X* cut in them, one for each core. Small rollers attached to the different cores engage these slots.

Just before the movable die withdraws from the stationary die after a casting has been made, bellcrank lever *Y* is swiveled through the action of a bellcrank lever at the rear of the machine which is actuated through the regular mechanism. Lever *Y* pulls rod *Z* upward and thus causes the right-hand cam-plate *W* to rotate on its axis. Spur-gear teeth cut on the rim of this cam-plate mesh with similar teeth on the rim of the left-hand cam-plate, so that both plates are revolved in unison in opposite directions. As this occurs, all cores of both die-cavities are withdrawn through the movement of the core rollers in grooves *X*. Reverse action occurs after the movable die has been advanced against the stationary die when the castings are being made. All sliding parts of both die members are hardened. Pipe connections are provided for the circulation of water for cooling purposes. Molten zinc is forced

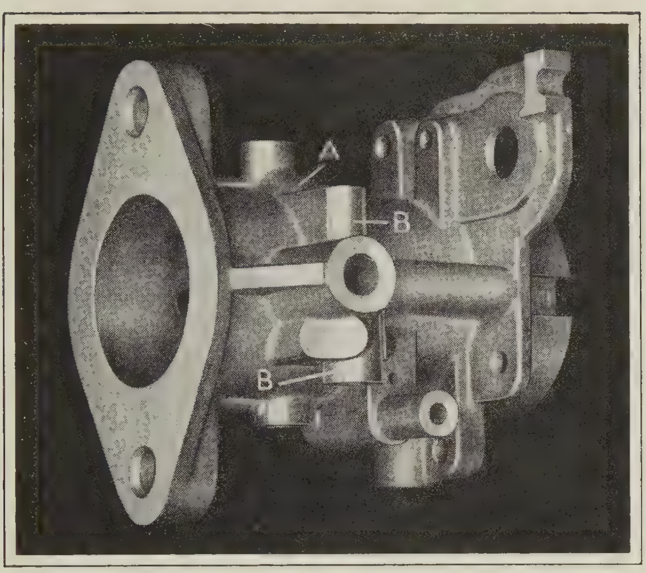


Fig. 7. Casting Produced in Dies Equipped with Eight Sliding Cores

into the dies for the casting operation under a pressure of 350 pounds per square inch.

Cores in Movable and Stationary Dies, which Must Register Accurately.—The set of dies for the casting, Fig. 7, has a sliding core of small diameter in the movable die that is required to register accurately with a similar core in the stationary die. Another feature of this die set is the use of a movable core for forming an under-cut surface in the casting.

The casting is a throttle valve body for a carburetor. It is cast in dies with the parting line running along the vertical center line of the casting, when viewed as shown in this illustration. In casting this part, the sliding cores of the movable and stationary dies must position themselves accurately against one another. The sliding core of the stationary die forms a hole in boss *A* that meets the hole formed in bosses *B* by the core of the movable die. These cores are illustrated at *C* and *D*, respectively, in Fig. 8; the

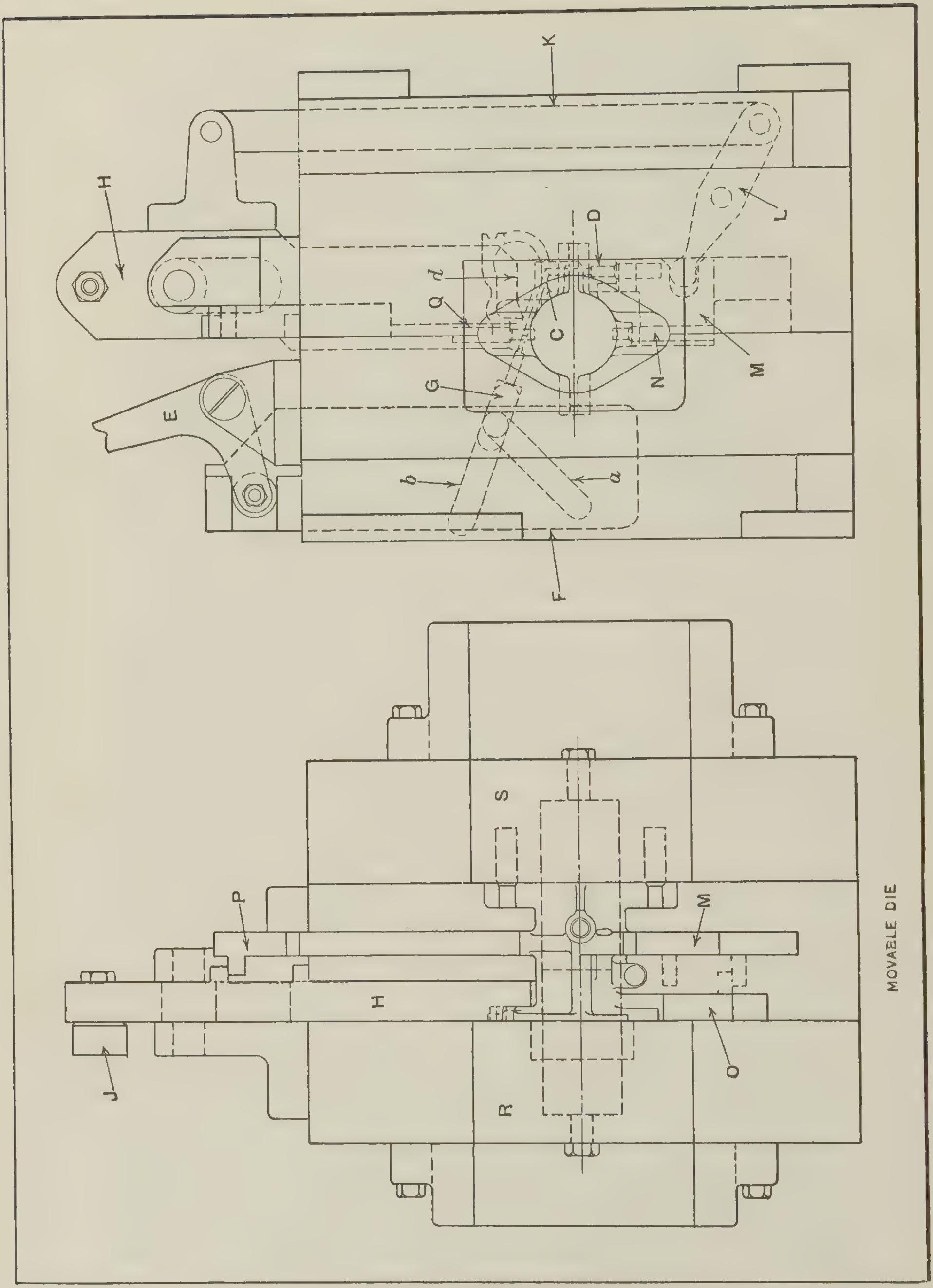


Fig. 8. Construction Details of a Die Set in which a Small-diameter Sliding Core in the Movable Die Must Register Accurately with a Similar Core in the Stationary Die

right-hand view shows the two dies together in the casting position, and the illustration at the left shows a view of the movable die face.

Core *C* must be slid into place after the dies have been closed for a casting operation. This core movement must take place quickly, as the molten metal is forced into the dies almost instantly when the dies are closed. Also, the core must be withdrawn before the movable die is pulled away from the stationary die, only enough time being allowed to elapse to permit the metal to solidify a certain amount. This core is 3/32 inch in diameter at the small end. It moves a distance of 2 inches, and therefore has considerable overhang at the point where it must meet core *D*, which also is but 3/32 inch in diameter at the small end.

How the Sliding Core of the Stationary Die is Operated.— The movements of core *C* are effected through bellcrank lever *E*, Fig. 8. This lever is actuated by a rod which connects it with another bellcrank that constitutes part of the regular mechanism of the machine. After a casting has been made, lever *E* is swiveled, which pulls slide *F* upward. This slide is provided with a cam groove *a* which is engaged by a roller fastened to holder *G* to which core *C* is attached. As a result, when slide *F* is raised, holder *G* is withdrawn along slot *b* in the die-block and the core is pulled back with it.

Operating the Sliding Cores of the Movable Die.— There are five sliding cores in the movable die, all of which are operated as slide *H* is moved up and down when the die carriage travels backward to open the dies and forward to close them. These movements of slide *H* are effected by roller *J* running along a path formed by cam-blocks on a combination bar mounted at the top of the machine.

When slide *H* is pulled upward, rod *K* causes lever *L* to swivel and thus pull down block *M* in which core *D* is held. The movement of this block and of the core is about

1 3/8 inches. Fastened to the same block there is also a core *N* which, of course, moves simultaneously with core *D*. During a part of the time that block *M* is in action, it conveys motion to slide *O* to which another core is attached. Slide *O* moves only a distance of 5/8 inch, the movement being controlled by two lugs on block *M* which come in contact with a lug on slide *O*. Obviously, this slide moves only when one of the lugs on block *M* is in contact with the lug on slide *O*.

At the lower end, slide *H* is shaped to form an under-cut surface in the casting, as indicated by the dotted lines *d*. Motion is also imparted to slide *P* by slide *H* through lugs similar to those employed in connection with block *M* and slide *O*. By this means, while slide *H* moves 1 3/8 inches, slide *P* moves only 1/2 inch. Attached to the lower end of slide *P* is a core *Q* which produces a hole in a boss on the casting directly on its center line.

The large hole that extends through the casting from end to end is formed by cores attached to blocks *R* and *S*. These blocks slide in ways in the face of the die body and in brackets attached to the die. The blocks are pulled outward as the movable die is withdrawn from the stationary die. Rods extending from the blocks have rollers at their outer ends which engage cam-blocks on combination bars mounted on both sides of the machine. As the rollers move along these cam-blocks, they pull the rods, together with blocks *R* and *S*, outward. In the present example, one rod suffices for each block.

Thus far only the action that causes the cores to be withdrawn from the dies and blocks *R* and *S* to be pulled apart after a casting operation has been discussed; when the movable die advances toward the stationary die before an operation, the reverse action of all moving die parts is effected. The part produced in these dies measures approximately 2 1/2 by 3 1/2 by 3 inches, and weighs about 1.2 pounds. The production averages 180 pieces per hour.

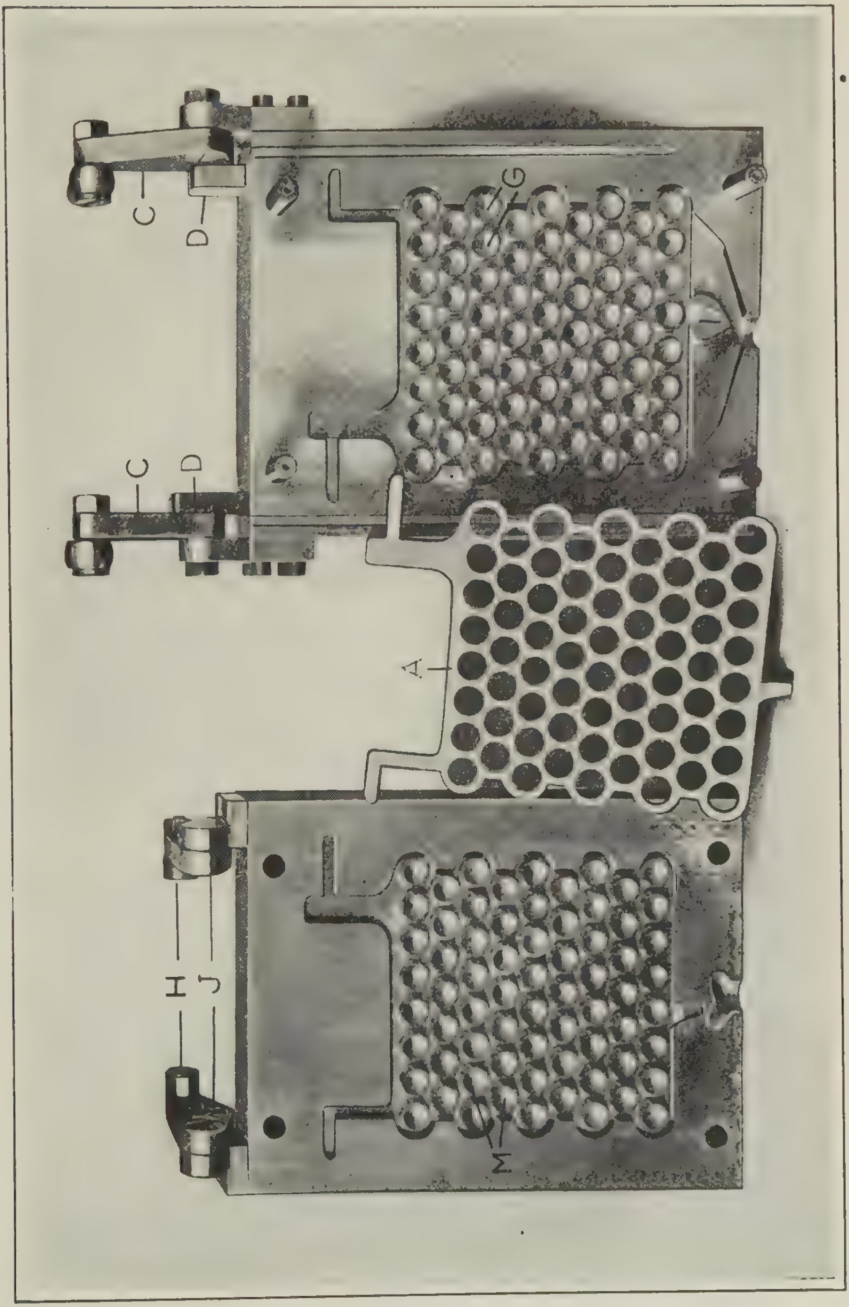


Fig. 9. Movable and Stationary Dies Equipped with Sixty-eight Sliding Cores Each for Producing the Holes in Battery Grid A

In casting, molten zinc is forced into the dies under a pressure of 350 pounds per square inch.

Die Set with One Hundred and Thirty-Six Moving Cores.—Movable and stationary dies with sixty-eight sliding cores each are used for casting lead battery grids of the type illustrated at *A*, Fig. 9. Cores are required in both dies, because a draft is allowed in the holes in both directions. The cores are moved 3/32 inch horizontally. The grids measure 10 1/8 by 7 3/4 inches, and are 5/16 inch thick. Approximately 1/16 inch of metal separates the different holes. These castings are produced at the rate of four per minute, the molten lead being forced into the die-cavity under a pressure of 150 pounds per square inch. In Fig. 9, the stationary die is shown at the right and the movable die at the left.

The cores of the stationary die are pulled from the casting before the movable die is withdrawn at the end of an operation, to insure that the casting will stick to the cores of the movable die. Movement of the stationary die cores is effected by two rods *B*, Fig. 10, connected to bellcrank levers at the rear of the machine which are operated by the standard equipment.

When these rods are pulled to the right, as viewed in Fig. 10, the two bellcrank levers *C* are swiveled, thus pulling the two slides *D* upward. Machined in these slides are two cam slots *a* which are engaged by rollers *E*. These rollers are fastened to the ends of plate *F* which contains all the cores in the stationary die. With this arrangement, as slides *D* are raised, plate *F* is moved horizontally an amount equivalent to the throw of the cam grooves. This is sufficient to pull cores *G* out of the casting.

Operating Cores of the Movable Die.—The cores of the movable die are withdrawn as the movable die carriage recedes from the stationary die and rollers *H* of levers *J* (Fig. 10) on the two sides of the die travel up the inclines

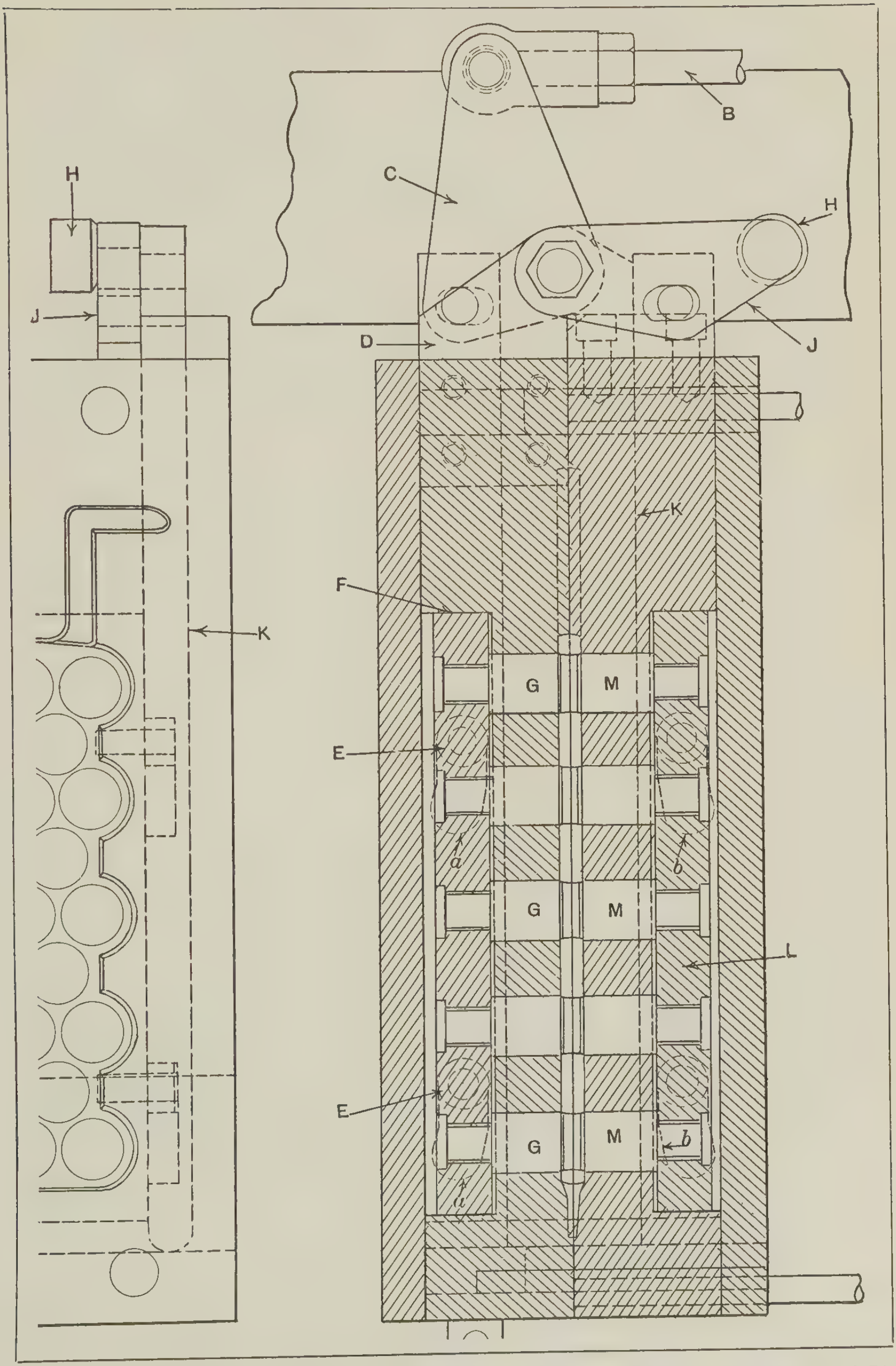


Fig. 10. Illustration Showing the Mechanism Employed for Moving the Cores of the Battery Grid Dies

of cam-blocks mounted on combination bars at the top of the machine. As this occurs, levers *J* swivel, thus lifting two slides *K*. These slides also have cam slots *b* similar to the cam slots in slides *D*, and rollers attached to plate *L* engage these slots. Consequently, when slides *K* are pulled up, plate *L* is shifted horizontally enough to pull cores *M* out of the casting.

Four pilot-pins are provided on the stationary die to enter mating holes in the movable die when the dies are closed. This insures close registry of the dies. The parting line is directly in the center of the casting.

Adjustable Dies for Parts of Different Dimensions

In the iron foundry, it is common practice to use one set of patterns and core-boxes for producing large castings that are identical except for length or width. The mold is merely cut off or extended to suit the dimensions of the different castings.

This age-old principle of the foundry has been applied by the Madison-Kipp Corporation, Madison, Wis., in designing modern die-casting dies.

Adjustable Dies for Typewriter Top Plates.—Typewriter top plates of the style illustrated in Fig. 1 are produced in three different lengths by means of the dies shown in Fig. 2. The lengths of the top plates are approximately 13, 16 1/2, and 20 1/2 inches. Inserts are provided at both ends of

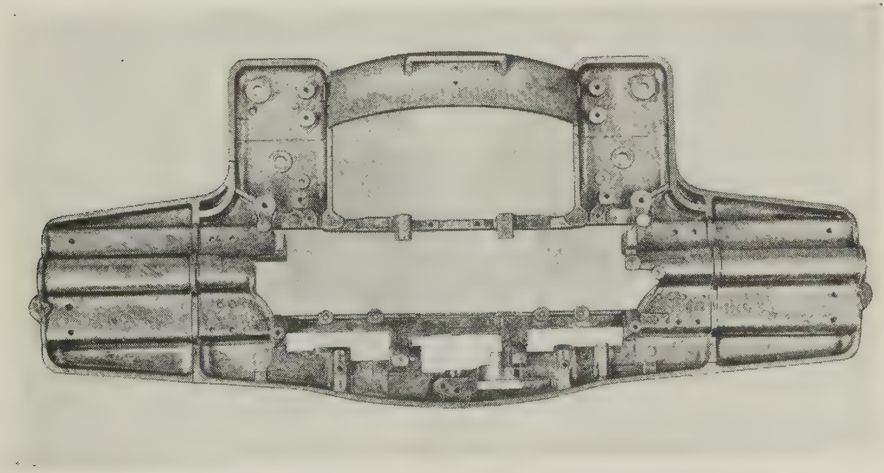


Fig. 1. Typewriter Top Plate, which Must be Produced within Close Tolerances in Spite of the Long Thin Sections and the Large Openings

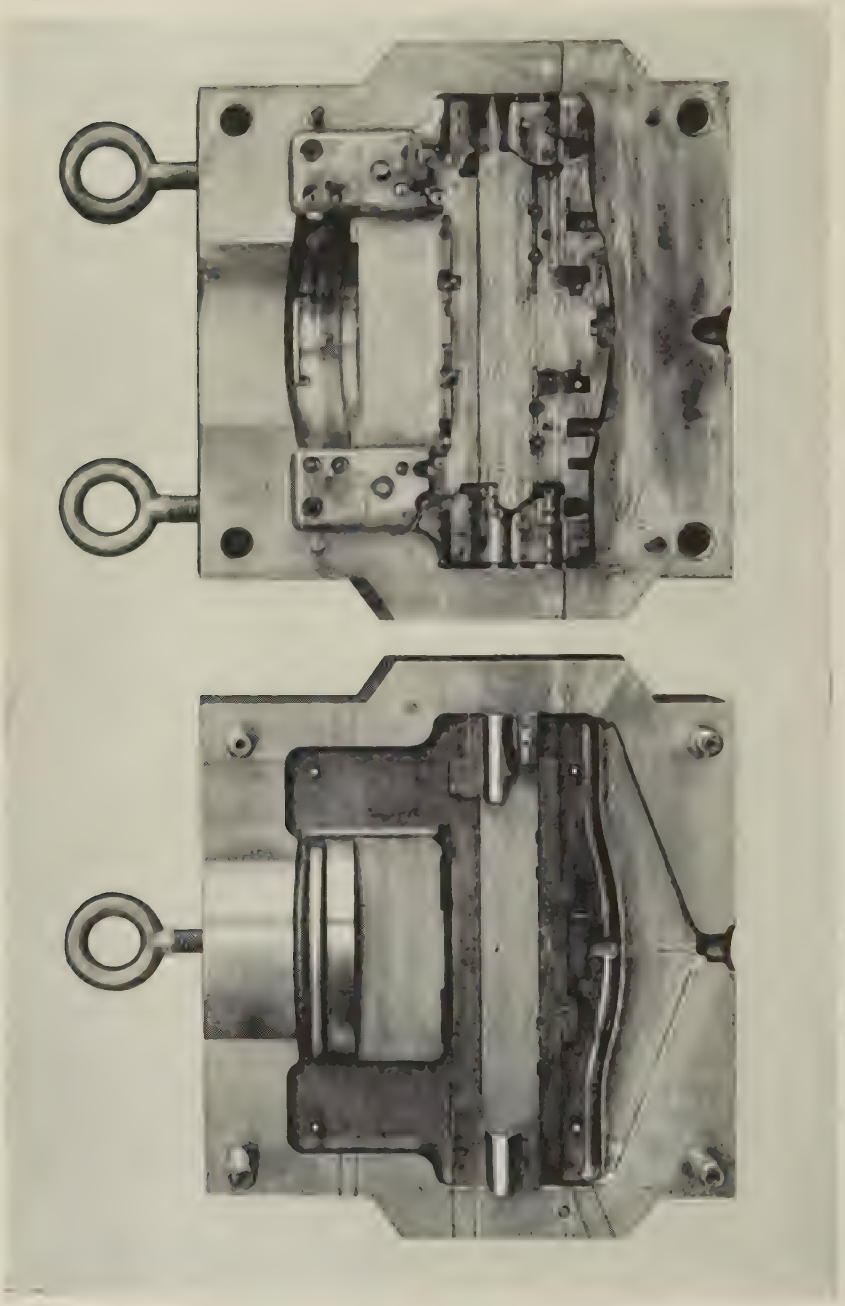


Fig. 2. Dies Arranged for Producing Typewriter Top Plates, Such as Shown in Fig. 1, in Three Different Lengths by Interchanging Inserts

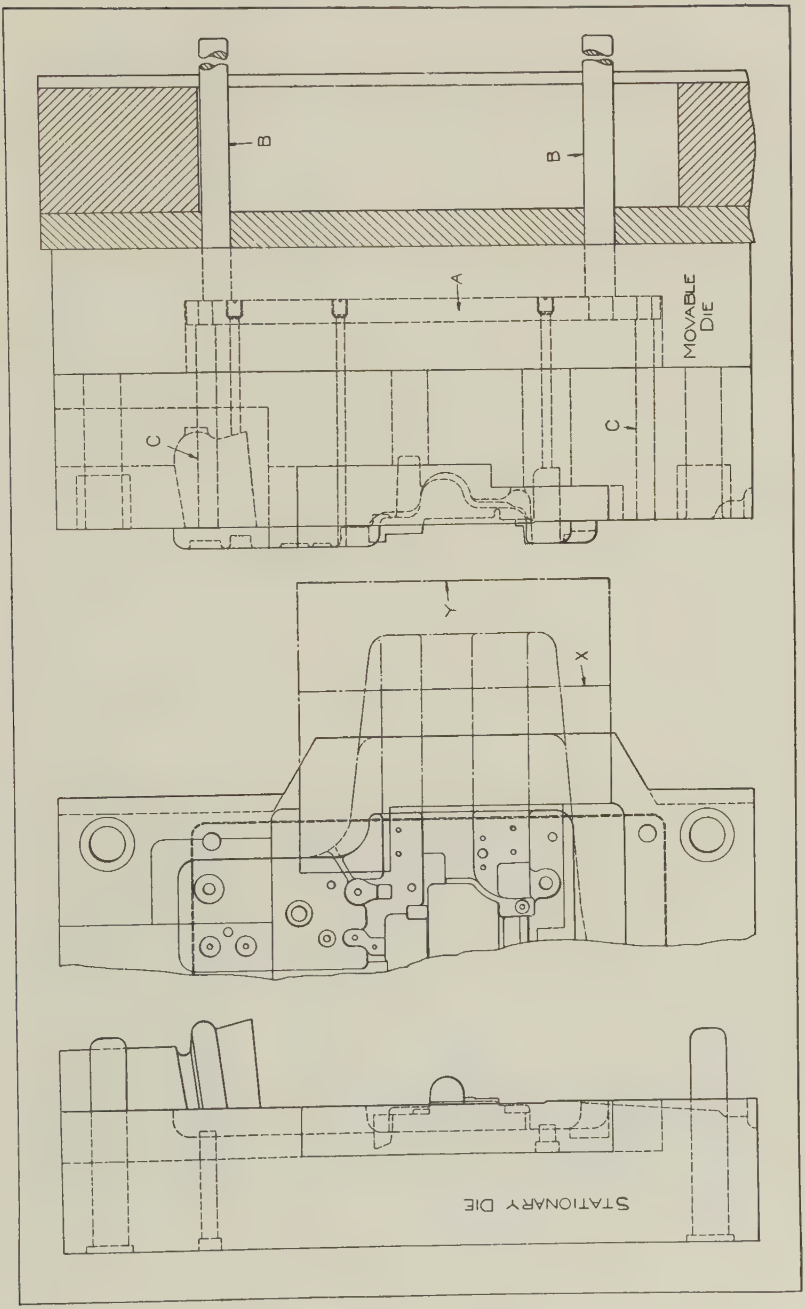


Fig. 3. Drawings that Indicate the Irregular Parting Line Required for Producing the Typewriter Top Plate Shown in Fig. 1

the dies, which are interchanged in order to produce castings of these three lengths. In Fig. 3, the dot-and-dash lines *X* and *Y* show the ends of the inserts used on one side of the movable die for producing castings of medium and greatest lengths, respectively, while the solid lines show the end of the insert that produces the shortest top plate.

Tolerances for the Cored Holes.—In Fig. 2, the dies are arranged for casting top plates of the shortest length, whereas the top plate in Fig. 1 is the largest of the three produced. In the longest top plate, there are fifty-one holes, ranging from 1/16 to 5/16 inch in diameter. The tolerance for the center-to-center distance between the holes at the extreme ends of the casting is plus or minus 0.002 inch. Holes of shorter center-to-center distances are held within plus or minus 0.001 inch. Practically all of the cores for producing the small holes are embodied in the movable die, which is shown at the right in Fig. 2.

Locating the Parting Line.—It is generally a comparatively easy matter to plan the paths of the parting lines, in

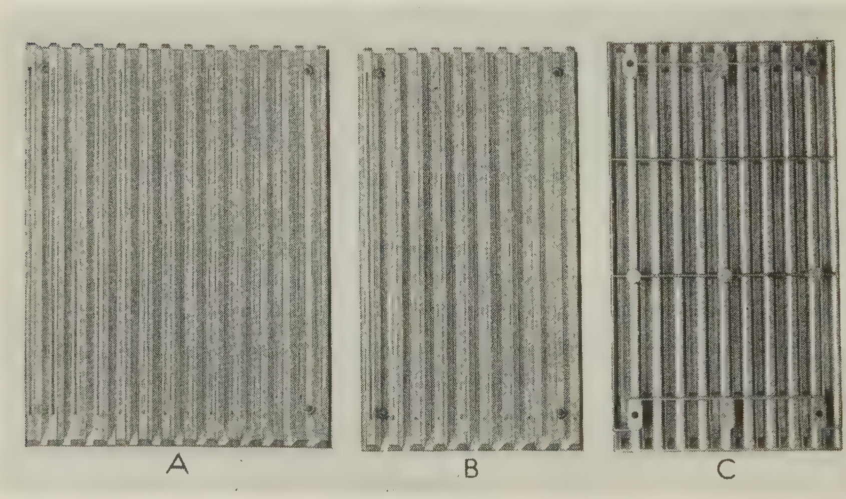


Fig. 4. Two Different Widths of Elevator Step Plates which are Cast in the Dies Shown in Figs. 5 and 6

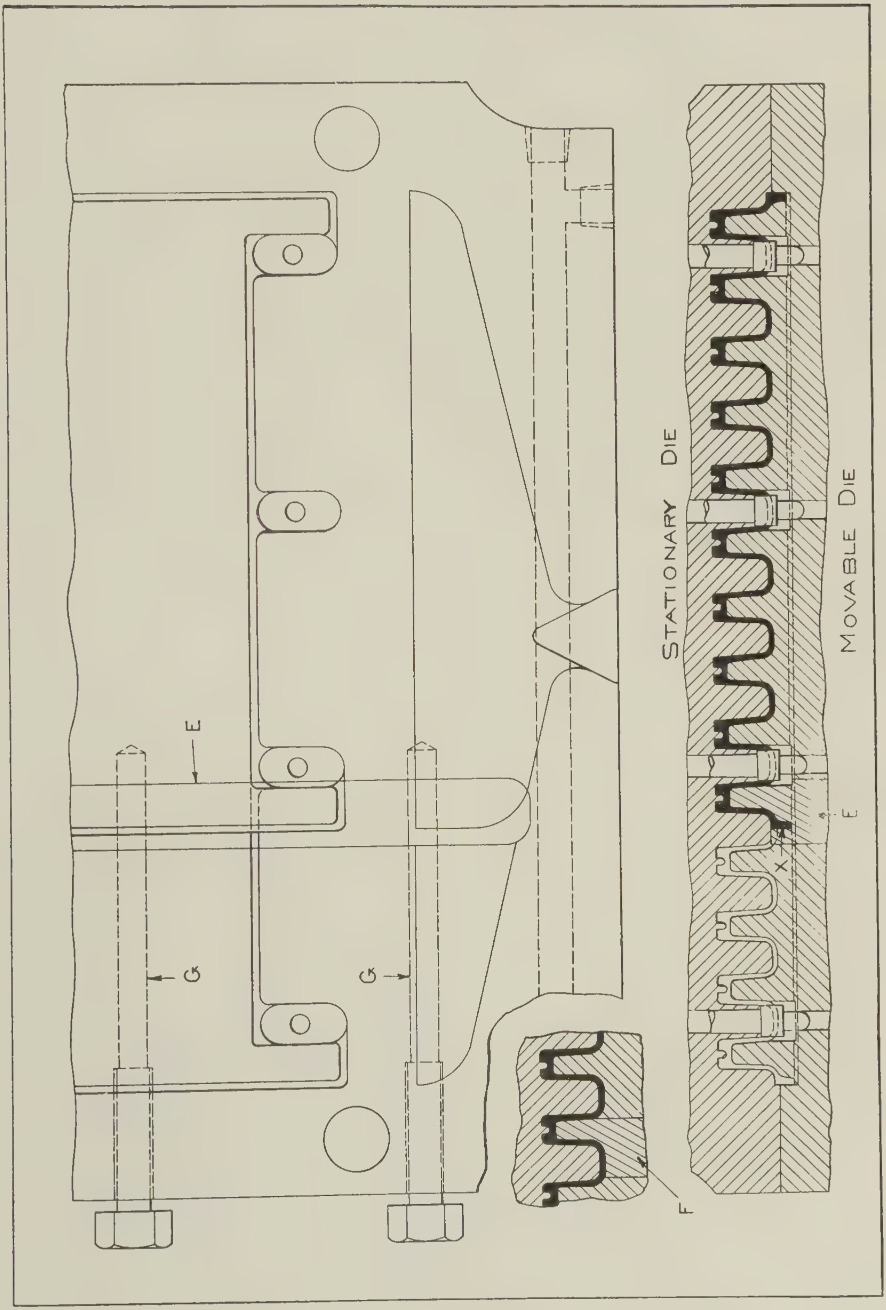


Fig. 5. Construction Drawing of the Dies that Produce Elevator Step Plates of Two Different Widths, Such as Shown in Fig. 4

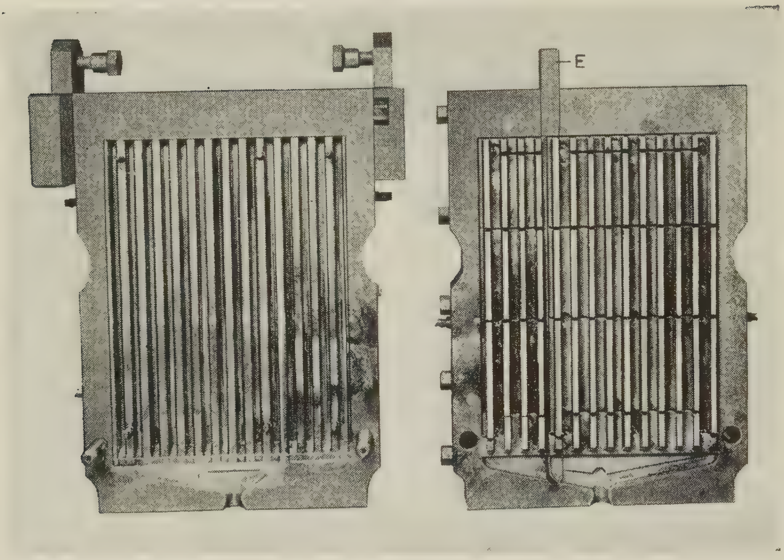


Fig. 6. Dies Designed for Casting Elevator Step Plates of Two Different Widths by Merely Changing the Insert Indicated at E

designing the average run of die-casting dies, but considerable difficulty was experienced in locating the parting lines for the dies used in making the typewriter top plates. These castings are of comparatively thin section for their entire length, and in spite of the large cored openings, the parts must be held straight within close limits. Before the parting lines could be decided upon, it was found necessary to make a clay model of a typewriter top plate from a pattern that had been submitted. The paths of the parting lines may be followed by studying the dies in Figs. 2 and 3.

Ejecting the Casting.—Thirteen ejecting-pins arranged on plate *A*, Fig. 3, force the casting from the movable die at the end of the operation. Plate *A* is actuated by four pins *B* which strike stops during the opening movement of the die. The ejector-pin plate is returned to the casting position when pins *C* come in contact with the face of the stationary die as the dies are closed. The typewriter top plates are cast from zinc, which has a melting point of about

810 degrees F. An average production of 45 castings an hour is obtained.

Adjustable Dies for Step Plates of Different Widths.—Elevator step plates of two different widths are shown at *A* and *B*, Fig. 4, and the under side of the narrow plate is shown at *C*. These two plates are also produced in one set of dies through the use of inserts which can be interchanged in the movable die member shown at the right in Fig. 6. When the narrow plate is to be produced, an insert of the design illustrated at *E*, Fig. 5, is used. This insert has a shoulder *X*, which shuts off the die-cavity and forms one end of the die-casting. When the wide step plate is to be cast, insert *E* is replaced by another having a cross-section such as illustrated at *F*. This insert continues the die-cavity and allows the metal to be forced to the extreme left-hand side of the cavity. The inserts can be conveniently interchanged by merely removing five screws *G*.

A large number of ejector-pins are required on the movable die because of the many long ridges of the casting, there being a total of sixty-seven ejector-pins all together. These elevator step plates are also cast from zinc. The rate of production averages 50 plates an hour.

Standards for Designing Die-Casting Dies

Die-casting dies must necessarily differ insofar as their cavities and cores are concerned, because these elements are obviously controlled by the design of the part to be cast. However, the mechanisms of dies may be the same in principle for a large variety of castings. This is true of methods employed for ejecting the castings from their dies; operating sliding cores; actuating sprue-cutters; supporting the dies on the machine; and so on.

Much time can be saved in designing die-casting dies if the draftsman has access to standard designs of die mechanisms and parts that are applicable under various conditions. The following pages present twenty-one standard designs which have been adopted as the regular engineering practice of the Madison-Kipp Corporation, Madison, Wis., in designing dies for automatic machines. These standards should serve as guides of incalculable value to the designer of die-casting dies; however, certain features of these designs are protected by patents.

Ejector for Removing Die-Castings from the Movable Die — Fig. 1.—The standard type of ejector for pushing the die-castings from the movable die at the end of each operation consists of ejector-pins *A* attached to a plate *B*, which is assembled in such a way as to allow a certain amount of relative movement with respect to the movable die. When this die approaches the end of its opening stroke, rods *C* contact against a bar stop on the die-casting machine and hold plate *B* stationary as the die completes the stroke. The movable die slips back along pins *A* so that they become extended into die-cavities *X*, and thus eject the castings from the cavities.

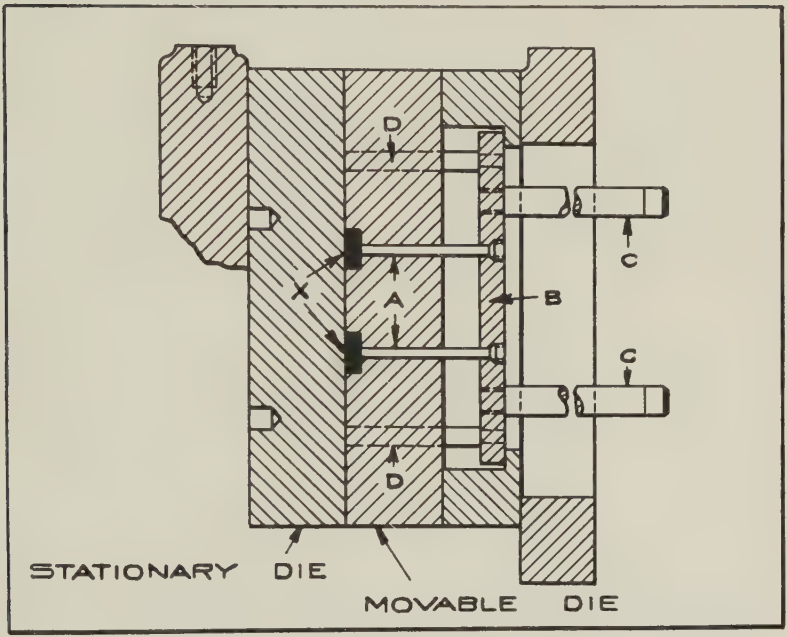


Fig. 1. Standard Type of Ejector Mechanism for Removing Die-castings from Movable Dies

When the movable die is closed against the stationary die preparatory to a casting operation, pins *D* contact against the face of the stationary die and by preventing further movement of plate *B* and the ejector-pins, return them to the positions shown. Any number of ejector-pins required to insure easy removal of the castings from the die can be provided on plate *B*, as the width and height of this plate can be varied to suit conditions.

Headless set-screws are screwed into tapped holes in plate *B* against the heads of ejector-pins *A* to fasten the pins to the plate. Rods *C* are threaded on one end for attaching to plate *B*, while pins *D* are merely a drive fit. Various numbers of rods *C* can be provided to meet requirements of individual parts.

Sleeve-Type Ejector — Fig. 2.—When there is a core in the center of a die-cavity, ejection of the casting from the mov-

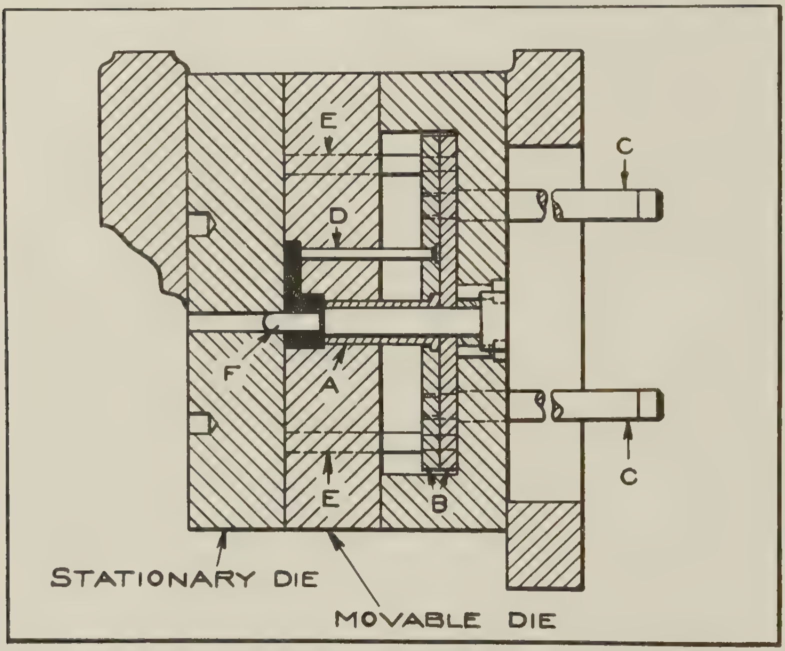


Fig. 2. Sleeve Type Ejector Frequently Applicable when a Die-casting Must Be Stripped from a Core in the Movable Die

able die can often be effected by the use of a sleeve *A*. This sleeve is attached to two plates *B*. When rods *C* strike against a bar stop on the machine as the movable die nears the end of its opening stroke, sleeve *A* is held stationary as the movable die and core *F* complete their movement. The sleeve, therefore, strips the casting off the end of the core and from the die-cavity. Standard ejector-pins can be provided as shown at *D* to loosen outer points of the casting from the die-cavity.

When the movable die closes against the stationary die preparatory to a casting operation, pins *E* contact against the face of the stationary die and, by preventing further movement of plates *B*, return the ejector sleeve *A* and pin *D* to the positions shown.

Sleeve *A* is provided with a shoulder that fits a recess in one of plates *B*. The second plate holds it to the first.

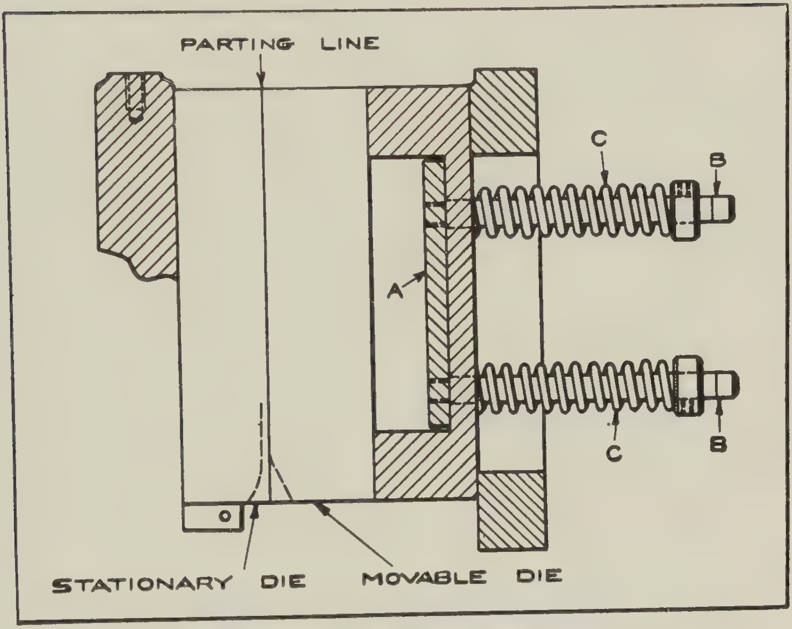


Fig. 3. Ejector Mechanism which Utilizes Springs for Effecting the Return Movement

Ejector with Spring-Actuated Return Movement—Fig. 3.— In some die-casting dies it is impractical to use the pins of the die standard illustrated in Fig. 1 for returning the ejector mechanism to the casting position at the time that the dies are closed. Under such a condition, the die standard shown in Fig. 3 is frequently applicable. This standard is also intended for use when ejector-pins of the type shown in Fig. 1 would interfere with the use of sliding cores in the die-cavity.

Plate *A* ejects the casting when rods *B* strike a bar stop on the machine as the movable die nears the end of its opening stroke. When this occurs, the movable die slides backward past the now stationary plate *A* with the result that the casting is automatically pushed from the die-cavity. Coil springs *C* are compressed with the completion of the die movement. These springs are held attached to rods *B*

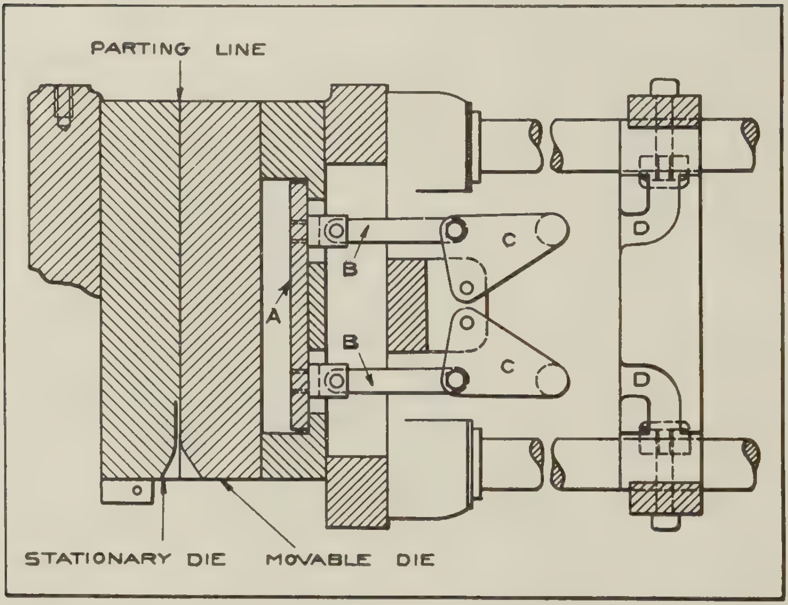


Fig. 4. Ejector Mechanism Operated by Cams with the Closing and Opening Strokes of the Movable Die

through the provision of collars that are held to the rods by headless set-screws.

When the movable die is again advanced toward the stationary die, springs *C* expand and retard plate *A* until it is again seated in the recess of the movable die as shown. This type of ejector return can also be frequently used in die designs where the standard ejector-pins of Fig. 1 are applicable. Any number of such ejector-pins could be provided on plate *A* to meet requirements.

Cam-Actuated Ejector — Fig. 4.—When the standard return pins of Fig. 1 cannot be used for returning the ejector mechanism to the casting position at the time that the movable die closes against the stationary die, the die standard shown in Fig. 4 may be used as an alternative to that illustrated in Fig. 3. Ejection of the casting from the movable die is effected by holding plate *A* stationary through the operation of links *B* and *C* as the movable die nears the end of its opening stroke. Links *C* are provided with rollers that enter cam-slots *D* on a bracket mounted in the center of the machine in back of the movable die.

During the opening stroke, plate *A* travels with the movable die until the rollers of links *C* enter the cam slots. The movement of the rollers then changes from horizontal to vertical. With this change in direction, the rollers swivel links *C* on their pivots and retard the movement of plate *A*, so that the casting is automatically forced from the cavity as the movable die completes its opening stroke.

When the movable die is again advanced toward the stationary die, links *C* are swiveled back into the position shown as their rollers withdraw from the cam slots. This action causes plate *A* to resume the position in which it is illustrated, ready for a casting operation. Ejector-pins may or may not be provided on plate *A*, depending upon the design of the casting produced in the dies to which this standard is applied.

Link- and Rod-Operated Ejector — Fig. 5.—This die standard provides a third alternative method of operating the ejector of a die-casting die when the standard return pins of Fig. 1 cannot be applied. Ejection of the casting occurs as plate *A* is prevented from further movement with the movable die when rods *B* strike a bar stop as the die approaches the end of its opening stroke. The casting is then forced from the die by means of ejector-pins mounted on plate *A*, the pins extending through holes in the movable die-block to the die-cavity.

Attached to the top of the movable die is a bracket on which link *C* is pivoted. This link is connected by a pin to another bracket *D* which is fastened to both rods *B*. During the opening stroke of the movable die, link *C* rides idly on the pin that connects it to bracket *D*. Upon the completion of this stroke, the link is almost vertical, a slot permit-

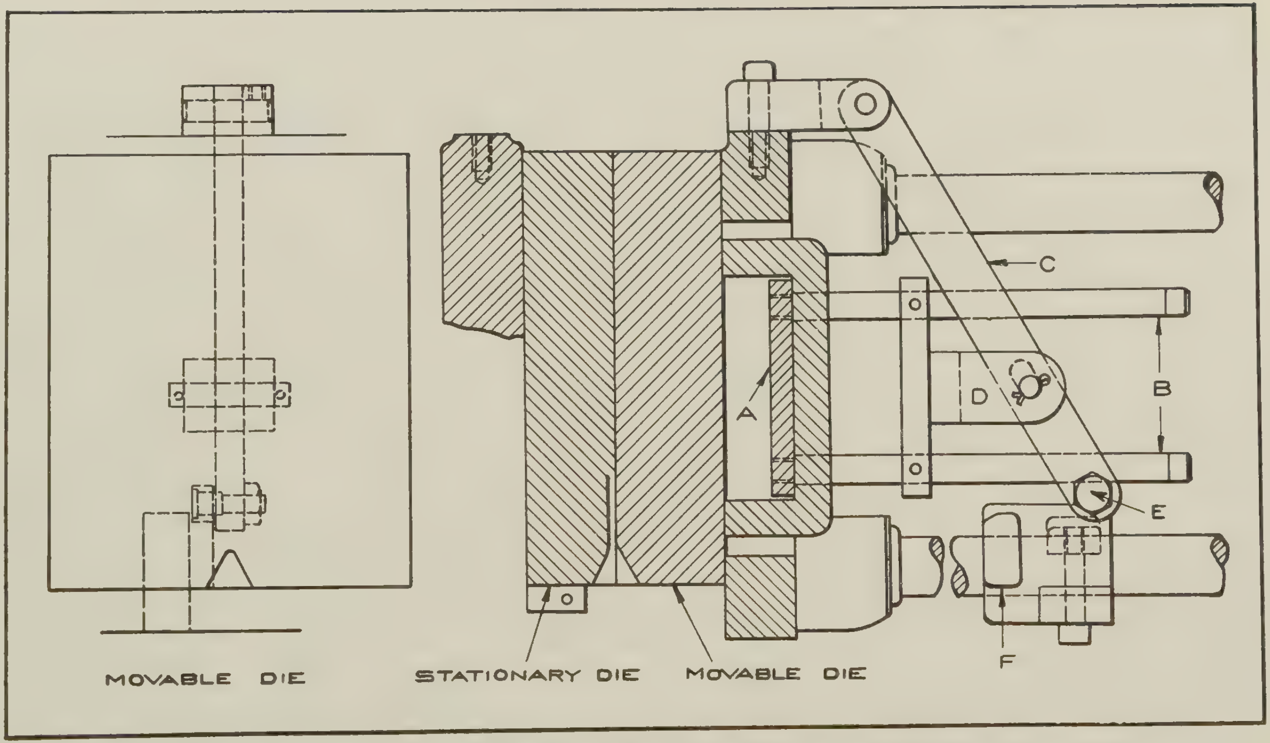


Fig. 5. Ejector Operated by the Conventional Rods on the Opening Stroke of the Movable Die and by a Link Contacting Against a Stop on the Closing Stroke

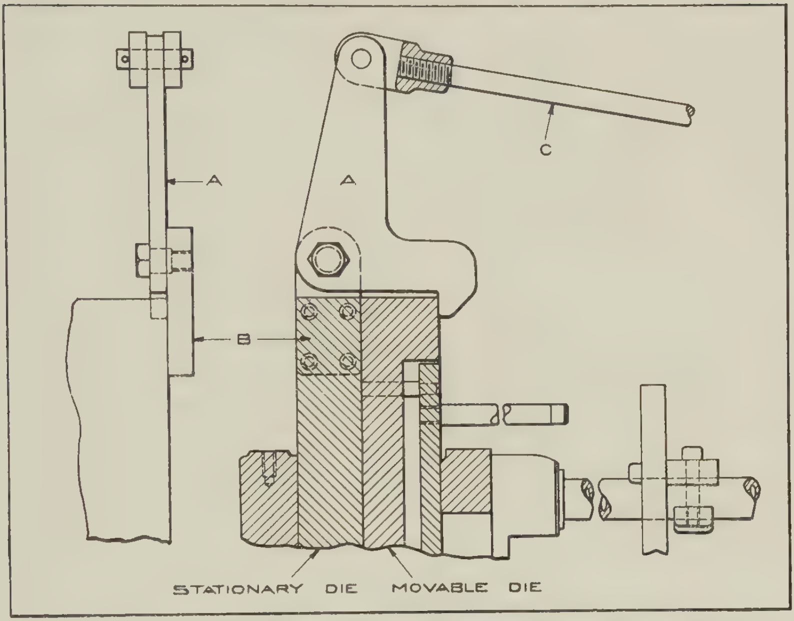


Fig. 6. Automatically and Hand Operated Clamp for Locking Unusually High Stationary and Movable Dies Together

ting the required play between it and the pin of bracket *D*.

When the movable die moves forward toward the stationary die, a roller *E* attached to the lower end of link *C* strikes against stop *F* which is mounted on one of the guide rails that the movable die carriage slides on. Thus the roller is prevented from further movement with the result that link *C* is again swung into the position shown and plate *A* is returned to the bottom of its recess in one of the movable-die parts. The bracket to which stop *F* is attached can be located as required along the guide rail.

Locking Device for Tall Dies—Fig. 6.—Dies taller than the standard height for which a die-casting machine is designed can be often used advantageously if means are provided to insure that the dies will not open up across their top edges upon the application of the heavy pressure required to force the molten metal into the die-cavity. Lock-

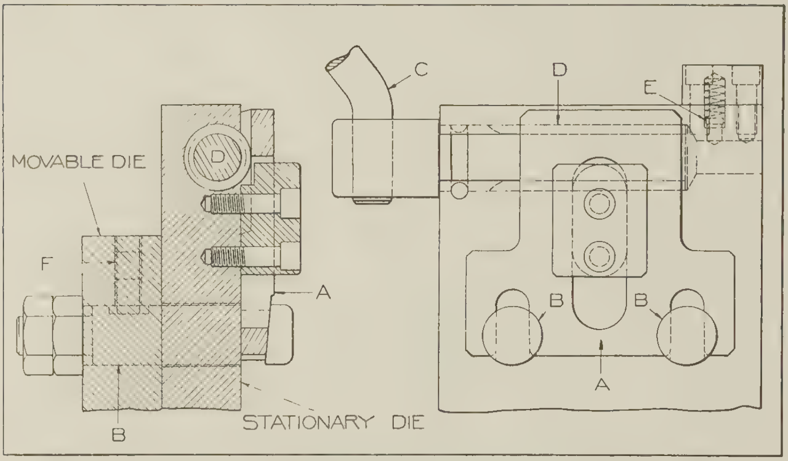


Fig. 7. Wedge Type of Die Lock which Is Operated Through a Rack and Pinion Arrangement

ing of the two dies together to guard against their separating can be accomplished by providing two auxiliary clamps *A* on brackets *B* fastened to the sides of the stationary die.

After the movable die has been closed against the face of the stationary die, these clamps are pulled down as shown through the operation of two rods *C* which, on Madison-Kipp automatic die-casting machines, are actuated by cam-operated levers that are regularly supplied. Upon the completion of each casting operation, clamps *A* are raised through the operation of rods *C* to permit the movable die to withdraw from the stationary die.

Clamps of this type can also be hand-operated, if required. They enable the application of high pressures to force the molten metal into the dies without any undue pressure being exerted on the mechanism of the die-casting machine itself.

Wedge-Type, Rack and Pinion Operated, Die Lock—Fig. 7.— Movable and stationary dies higher than the standard size for which a die-casting machine is designed can also be securely held together for the casting operation by employing the wedge type of lock shown in Fig. 7. A block *A* mounted at the top of the stationary die is merely entered under the heads of two bolts *B* after the movable die has been closed against the stationary die. At the time that the movable die approaches this position, the heads of bolts *B* pass through the holes in the stationary die, sufficient clearance being provided. When the movable die withdraws at the end of each operation, bolts *B*, of course, slide back through these holes.

Block *A* and the heads of bolts *B* are wedge-shaped so that the movable die is pulled firmly against the stationary die when block *A* is advanced into the position illustrated. The tightness of the fit between the tapered surfaces of block *A* and the heads of bolts *B* may be adjusted by means of the nuts on bolts *B*. Block *A* is operated manually by turning handle *C* to revolve a pinion shaft *D* which has spur-gear teeth for a length of 3 1/2 inches. The pinion teeth engage rack teeth machined on the back of block *A*.

A spring detent *E* engages spots drilled in the lower end of the pinion shaft to prevent this shaft from turning by itself. Threaded studs *F* retain bolts *B* on the movable die.

A wedge lock of this type has proved entirely satisfactory for holding dies securely together that are used in casting a part 20 inches long on a manually operated die-casting machine that is designed to receive dies only 6 by 6 inches square.

Guide Pins and Guide Blocks that Insure Correct Die Registry — Fig. 8.—Four guide pins such as shown at *A* are ordinarily provided on the stationary die to enter bushings *B* inserted in the movable die. This insures proper registry of the two dies each time that the movable die is closed against the stationary die. The guide pins are conventionally made 3/4 inch in diameter and are positioned two near the bottom of the dies as shown and two near the top. Sometimes the bushings are omitted, the guide pins then registering in holes in the movable die itself.

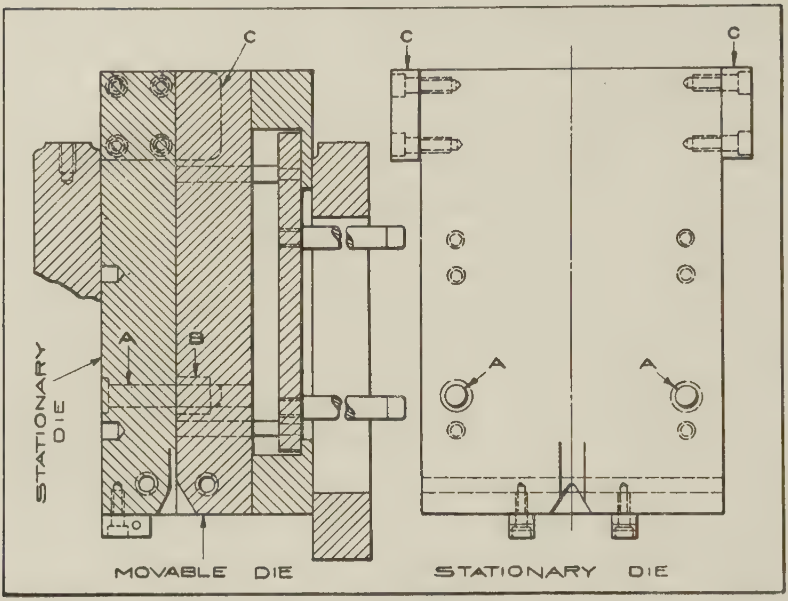


Fig. 8. Guide Pins and Guide Blocks which Insure Correct Registry of the Dies when They Are Closed

When a set of dies is intended for use in casting aluminum or other metals of high melting temperatures, there is often a considerable dimensional change in the dies when they become hot. Under this condition, undue binding would occur between the guide pins and their bushings if guide pins were used at both the top and bottom of the dies. Guide pins made sufficiently loose to overcome the binding would not insure correct registry of the dies at all times.

Dies intended for casting high-temperature metals are generally provided with two guide pins near the bottom as shown and two guide blocks *C* at the top. These guide blocks are also fastened to the stationary die. They contact against the sides of the movable die when the latter is closed against the stationary die and thus insure correct registry of the dies at all times regardless of their temperature.

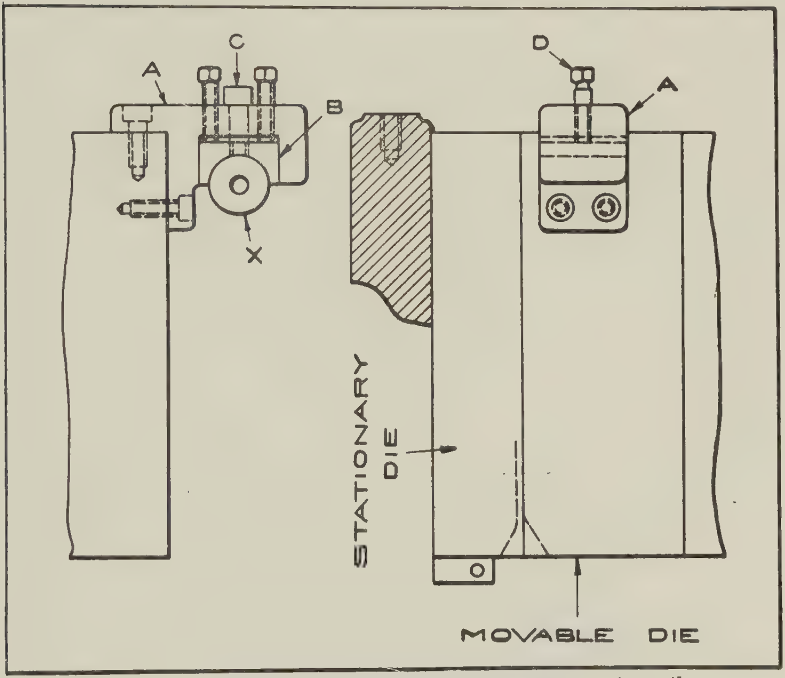


Fig. 9. Brackets and Shoes for Supporting the Movable Die on the Guide Rails of Die-casting Machines

Support Bearings for Movable Dies—Fig. 9.—When the movable die is to be supported by guide rails on the die-casting machine, brackets of the style shown at *A* may be attached to each side of the movable die at the top. These brackets are provided with renewable shoes *B* which ride on the guide rails *X* on opposite sides of the machine. Each shoe is attached to its corresponding bracket *A* by a screw *C* and is adjusted to the required height relative to the die by means of two set-screws *D*.

Sprue Cutter for Multiple-Cavity Dies—Fig. 10.—When a number of small similar pieces are cast at one time in multiple-cavity dies, it is often advantageous to shear the castings from the sprue or gate metal while they are still in the dies. This avoids a separate trimming operation on each casting.

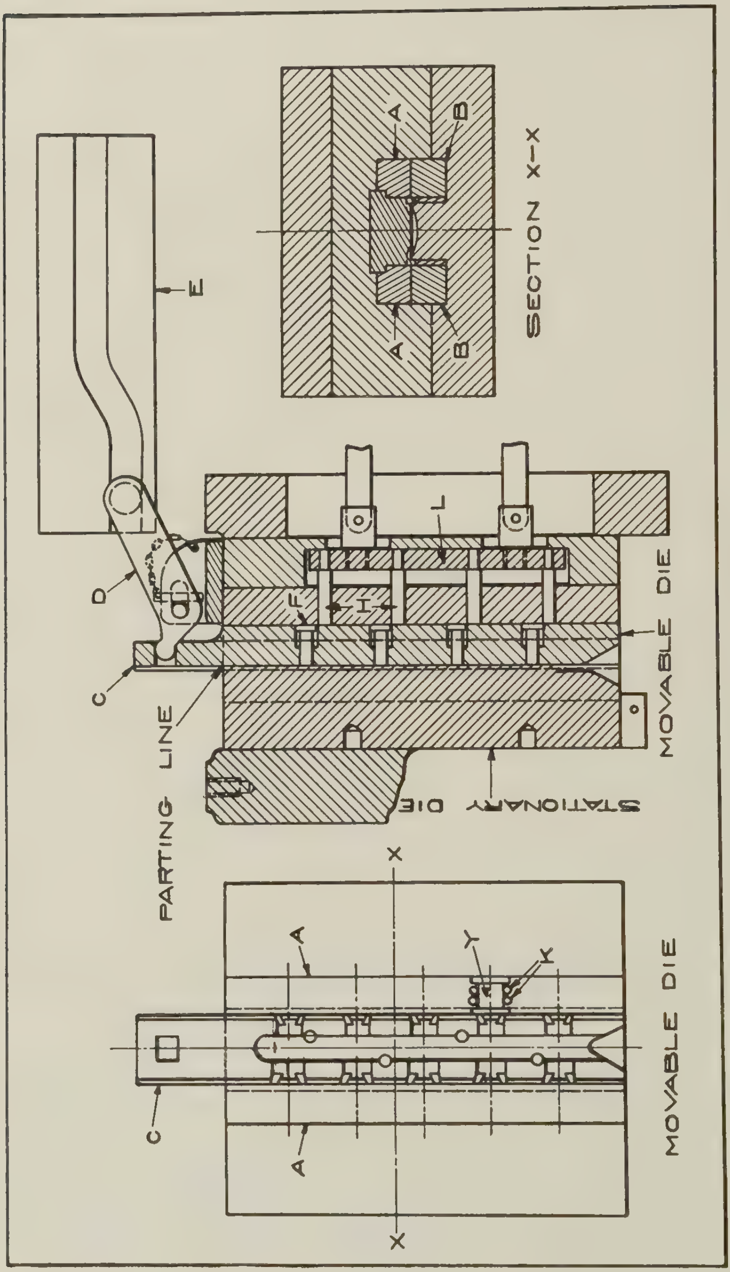


Fig. 10. Sprue Cutter which Severs the Castings of Multiple-cavity Dies from the Sprue or Gate Metal

In the typical example illustrated in Fig. 10, it is assumed that there are ten cavities *Y* in blocks *A* and *B* of the movable and stationary dies, respectively. When the movable die withdraws from the stationary die at the end of each operation, slide *C* is pushed downward due to the action of link *D,* as a roller attached to the one end of this link travels along a cam path in bar *E*. This bar is mounted in the center of the machine. Link *D* is pivoted on a pin that passes through two brackets mounted on top of the movable die.

The downward movement of slide *C* results in the ten castings being sheared free from the gate by fine teeth on hardened-steel inserts provided on the slide at the points where the shearing action occurs.

At the end of the downward movement of slide *C,* the auxiliary ejector-pins *F* in slide *C* are directly in line with ejector-pins *H* which are mounted on plate *L* in the conventional manner. Pins *H* then bear against pins *F* and, by holding them stationary as the movable die nears the end of its opening stroke, force the gate metal from the face of slide *C*. Four ejector-pins *K* are also provided around each cavity to act against lugs cast on the parts for this purpose. Pins *K* are attached to plate *L* and force the individual castings from the movable die. Pins *H* are returned to the positions shown when the movable die is advanced toward the stationary die by a mechanism similar to that shown in Fig. 4. Pins *F* are pushed back into the positions illustrated when the movable die contacts against the stationary die.

Water-Cooling Provisions in Multiple-Cavity Dies and Rack-and-Pinion Core-Moving Mechanism—Fig. 11.—To avoid excessive overheating of multiple-cavity dies, it is often necessary to make arrangements for circulating cooling water in the vicinity of the die-cavities. In the 8-cavity die illustrated in Fig. 11, a long hole *X* is drilled in the

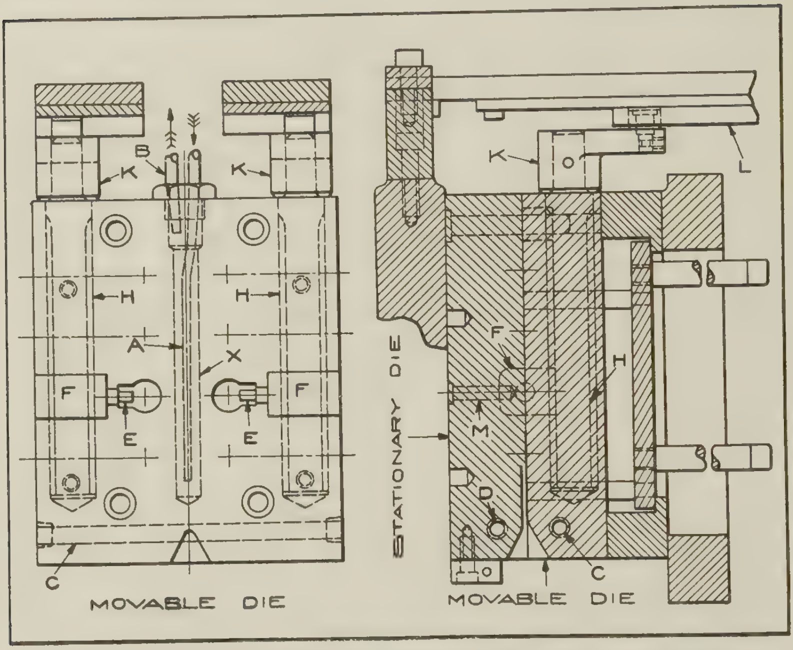


Fig. 11. Provisions for Water-cooling Multiple-cavity Dies and for Operating Sliding Cores

center of the movable die-block. Inserted in this hole is a tube *A* which is of such a length that it extends almost to the bottom of hole *X*. Water forced into tube *A* leaves the tube at the lower end and rises along the wall of hole *X*, cooling the die in the vicinity of this hole and leaving the die through pipe *B*. Similar provisions can be made to water-cool the stationary die.

On practically all die sets, holes are drilled across the bottom of both the stationary and movable dies as illustrated at *C* and *D* to enable the circulation of water for cooling purposes.

Fig. 11 also shows a popular method of operating cores parallel with die faces. Assume that a core *E* mounted in a holder *F* projects into each cavity when the dies are closed. Rack teeth provided on the back of each core-holder are engaged by pinion teeth machined on shafts *H*.

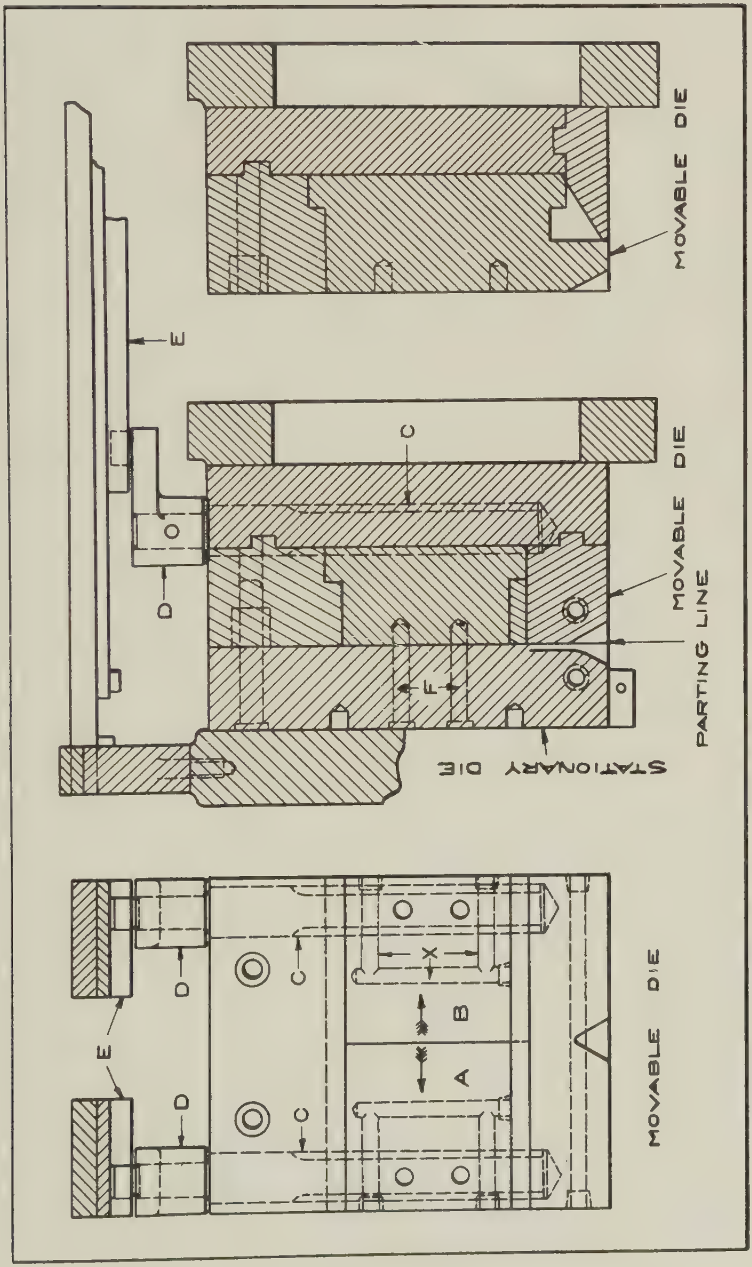


Fig. 12. Movable Die with Sliding Blocks that Open Sidewise as the Die Withdraws from the Stationary Die

When the movable die recedes from the stationary die at the end of each operation, the pinion shafts are revolved as rollers attached to levers *K* follow cam paths formed by bars *L* mounted on top of the machine. The pinion shafts, in turning, withdraw cores *E* and core-holders *F* sideways from the die-cavities. The cores are again advanced into the die-cavities through the reverse operation of the mechanism when the movable die is returned against the stationary die. Pins *M* are provided in the stationary die to register in holes of the core-holders when the dies are closed, so as to lock the cores in the casting position.

Movable Dies that Open Sidewise and Endwise—Fig. 12.— The shape of a die-casting frequently necessitates that the dies be opened sidewise in addition to endwise so as to enable ejection of the casting. This condition exists, for example, with a casting that is cored out externally on the sides.

When the movable die must be opened sidewise, the cavity may be formed in two slides *A* and *B* which are mounted on the face of the movable die. These slides are provided with rack teeth which are engaged by teeth cut on shafts *C*. When the movable die recedes from the stationary die at the end of each operation, these pinion shafts are revolved as rollers attached to levers *D* follow cam paths provided by bars *E* which are mounted on top of the machine.

Slides *A* and *B* are again moved together through the reverse operation of the mechanism when the movable die is returned against the stationary die. Two pins *F* are furnished on each side of the stationary die to engage holes in slides *A* and *B* and thus lock them in the closed position for the casting operation. Holes can be drilled in slides *A* and *B* as indicated at *X* for water-cooling the die-cavities.

Two alternate methods of securing slides *A* and *B* to the face of the movable die are shown by the middle and right-hand views of Fig. 12.

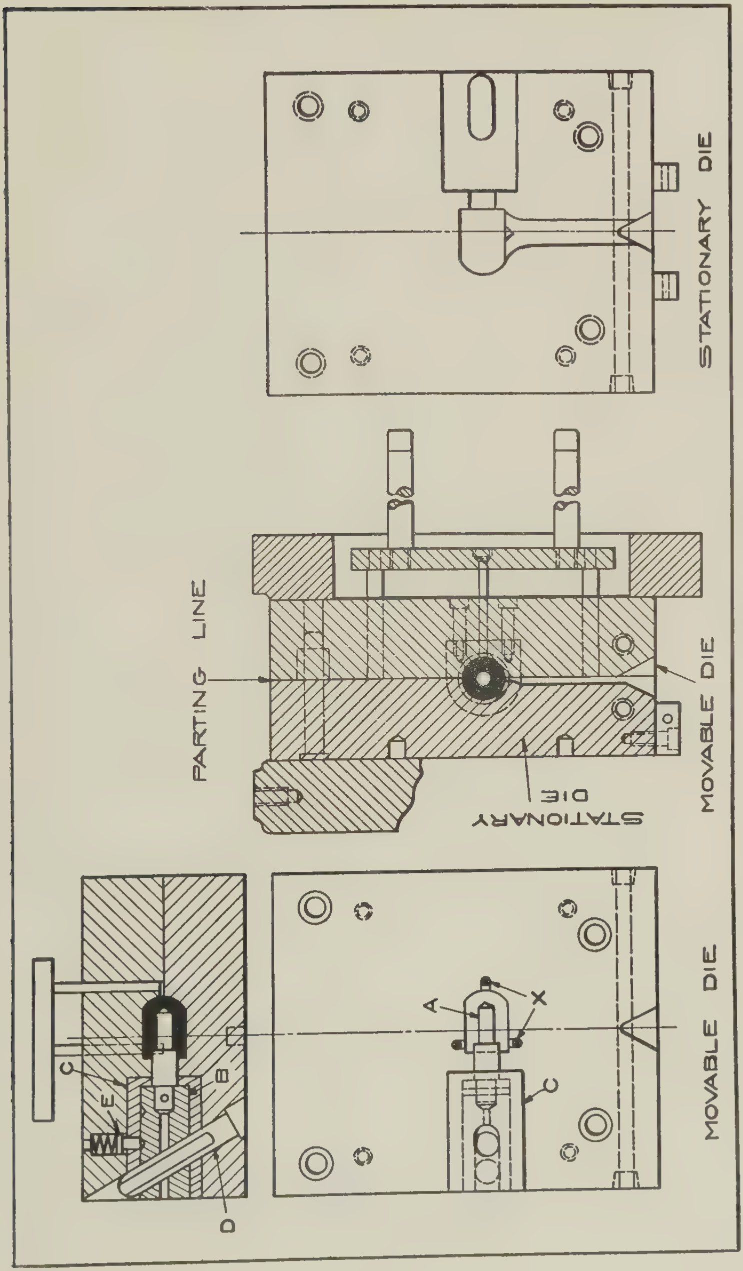


Fig. 13. Method of Operating a Sliding Core on the Movable Die by Means of a Fixed Pin on the Stationary Die

Sliding Core on Movable Die Operated by Pin on Stationary Die—Fig. 13.—Unless cores extend into the die-cavity at right angles to the faces of the movable and stationary dies, it is generally necessary to provide means of withdrawing them from the cavity in order to permit ejection of the casting. Various standard methods have been devised for automatically operating such sliding cores.

In the standard design illustrated in Fig. 13, core *A* is mounted in a slide *B* which operates in block *C*. This block is fastened to the front of the movable die. Extending at an angle from the face of the stationary die, there is a pin *D* which is designed to engage an angular hole in slide *B* when the movable die approaches the stationary die at the beginning of each operation. At this time the angular relation of pin *D* and the corresponding hole in slide *B* causes the slide to move laterally for advancing the core into the die-cavity as shown.

When the movable die withdraws from the stationary die at the end of each operation, the core is pulled sidewise from the die-cavity as slide *B* slips off the end of pin *D*. The casting can then be easily ejected by employing ejector-pins of the conventional type. Spots should be drilled in slide *B* and a spring detent provided in the movable die as shown at *E* to lock the core slide in its inner and outer positions. The face of the stationary die must, of course, be hollowed out to receive block *C*.

Care must be taken in such a design to insure that none of the ejector-pins will interfere with sliding cores. This may be guarded against by arranging for the formation of small "ears" of flash at certain points around the casting as indicated at *X* and then locating ejector-pins so that they will act on these ears.

Rack-and-Pinion Method of Operating Sliding Cores—Fig. 14.—Rack-and-pinion mechanisms can be used extensively to operate sliding cores under a wide variety of con-

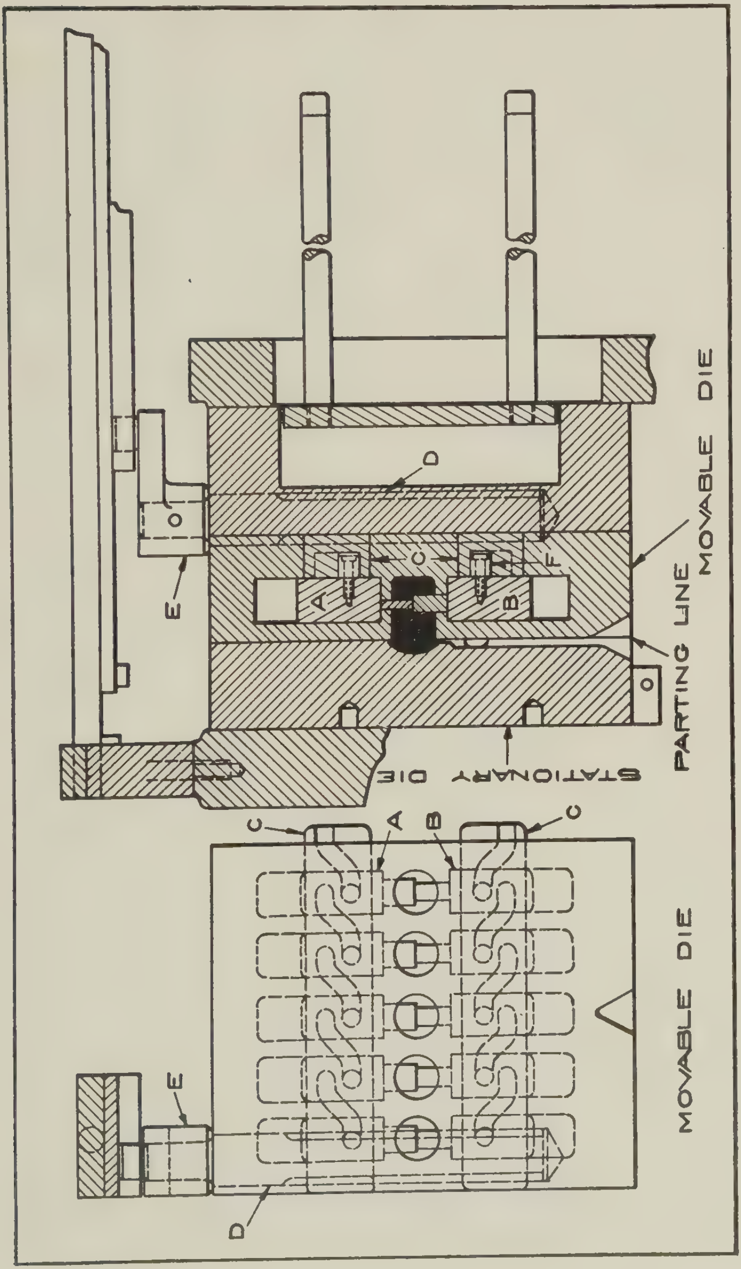


Fig. 14. Rack-and-Pinion Mechanism which May Be Employed for Operating Sliding Cores in Single- or Multiple-cavity Dies.

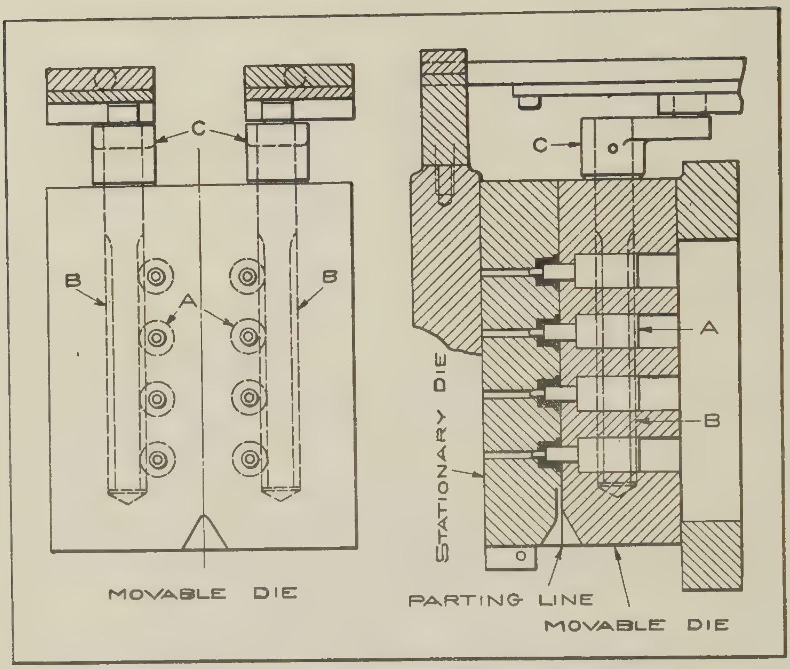


Fig. 15. Arrangement for Actuating Series of Sliding Cores at Right Angles to the Faces of the Dies

ditions. In the multiple-cavity die illustrated in Fig. 14, two cores must be moved vertically toward each other into each of five cavities when the movable die closes against the stationary die. These cores must, of course, be withdrawn from the cavities at the end of every operation.

The cores are mounted in ten holders *A* and *B* which are provided with small rollers as shown at *F* that engage bayonet-type cam slots on slides *C*. These slides are provided with rack teeth on the back side which engage spur-gear teeth cut on shaft *D*. Shaft *D* is turned a partial revolution as a roller on the arm of lever *E* follows the cam path of bars mounted on top of the machine, when the movable die is withdrawn from the stationary die at the end of an operation.

When this movement of the pinion shaft occurs, both bars C are pulled to the left and the cores are withdrawn vertically from the respective cavities due to the action of the rollers on holders A and B as they follow the cam paths on slides C. The cores are, of course, returned into the die-cavities as illustrated when the movable die is again closed against the stationary die and the operation of the entire mechanism is reversed.

Sliding Cores Moved at Right Angles to the Die Faces—Fig. 15.—With some classes of work cores must be moved at right angles to the faces of the dies. This can sometimes be effected by mounting the cores in holders A, Fig. 15, which are arranged to slide in the movable die. Rack teeth are provided on the back of these holders for engaging pinion shafts B so that the cores are operated to or from the die-cavities as rollers attached to levers C follow the cam paths of bars mounted on top of the machine.

In the particular die set illustrated, the die-cavities are entirely contained in the stationary die. The face of the movable die serves merely to close the tops of the cavities.

Sliding Cores Actuated by Pull-Rod and Rack-and-Pinion Mechanisms — Fig. 16.— Rack-and-pinion mechanisms for the operation of sliding cores can also be actuated by a lever A mounted on a pinion shaft B and connected through a pull-rod C to some prime mover on the die-casting machine. Shaft B is provided with spur-gear teeth at both ends which engage rack teeth cut on the back of two slides D. On the front sides, these slides are provided with a series of cam slots which engage rollers attached to core-holders E.

When a partial revolution is imparted to the pinion shaft B before the movable die withdraws from the stationary die, slides D are moved downward. At this time, the action of the cam paths on the rollers that are attached to core-holders E causes the core-holders to be pulled sidewise so that all of the cores are withdrawn from the die-

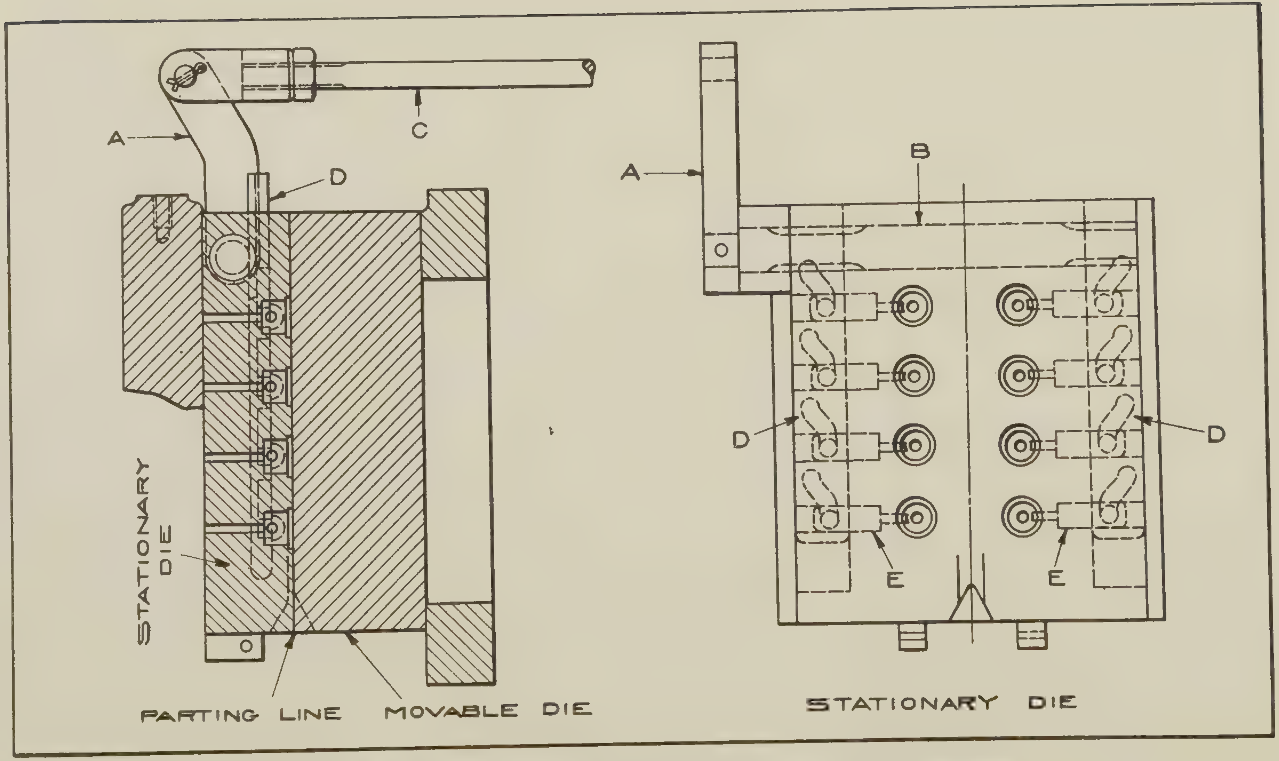


Fig. 16. Sliding Cores Actuated by a Pull Rod and a Rack-and-Pinion Mechanism

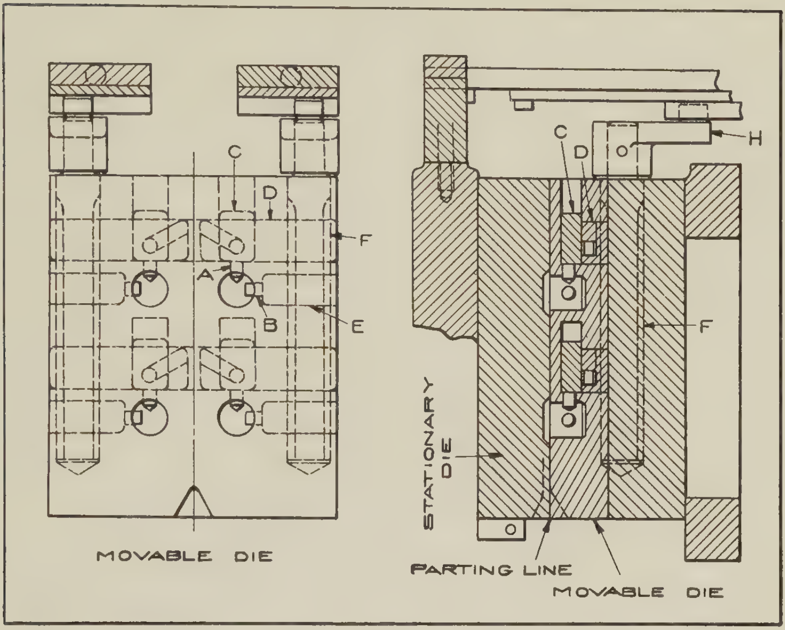


Fig. 17. Sliding Cores Moved in Different Directions by One Mechanism

cavities. Slides *D* are again pulled upward when pinion shaft *B* is rotated in the reverse direction as the movable die is returned against the stationary die and thus return the core-holders toward the center of the stationary die and the cores into the die-cavities.

In dies designed to function in the manner described, all of the mechanism is contained in the stationary die. The movable die serves merely to close the top of the various die-cavities.

Sliding Cores Moved in Different Directions by One Mechanism—Fig. 17.—One mechanism can often be employed to move several sliding cores in different directions. The four cavities of the dies illustrated in Fig. 17 are each provided with a core *A* that must be moved vertically and a core *B* that must be operated horizontally. Each core *A*

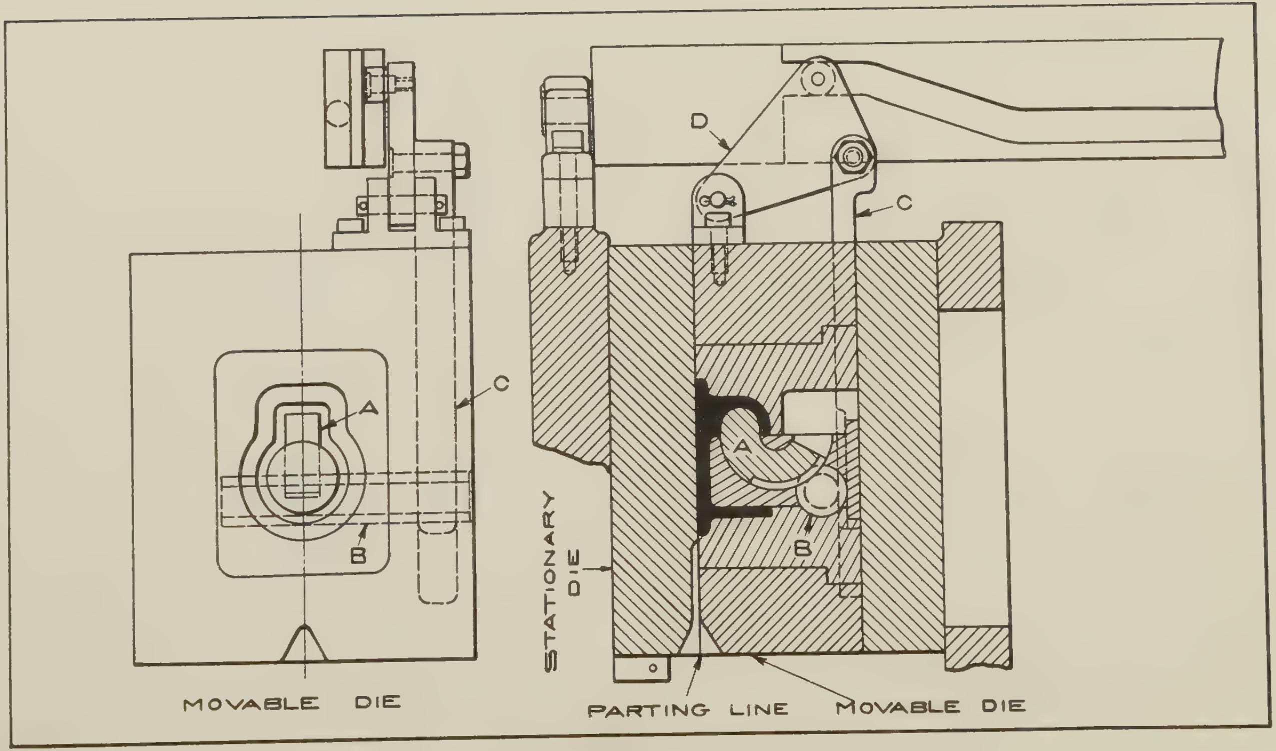


Fig. 18. Mechanism for Rotating Cores into and out of Die-cavities

is mounted in a holder *C* which is provided with a roller that engages a cam slot in slide *D*. Core *B* is mounted in a holder *E* which has rack teeth on the back that are engaged by pinion shaft *F*. The back of each slide *D* is also provided with rack teeth that engage the pinion shaft.

When the movable die recedes from the stationary die at the end of each operation, pinion shaft *F* is turned as a roller fastened to lever *H* follows a cam path in bars mounted on top of the machine. The turning of the pinion shaft causes holders *E* and their cores *B* to be pulled sidewise from the die-cavities. Also, through the action of the cam slots of slides *D* on the rollers of holders *C*, these holders and their cores *A* are pulled upward. The reverse movements of these various die members, of course, occur when the movable die returns to the stationary die for each succeeding operation.

Cores Rotated into and out of Die-Cavities—Fig. 18.— Sometimes the design of a die-casting die is such as to require a sliding core of odd shape, as indicated at *A* in Fig. 18. A core of this type may be operated by providing spur-gear teeth around a circular edge for engaging corresponding teeth cut on a shaft *B*. The teeth of this pinion shaft are, in turn, engaged by rack teeth provided on a slide *C*. The upper end of slide *C* is connected to a plate *D* pivoted on a bracket mounted on the movable die. This plate is provided with a roller which rides in a cam path formed by bars mounted on top of the machine.

When the movable die withdraws from the stationary die at the end of each operation, slide *C* is pushed downward as the roller of plate *D* follows the cam path. This causes pinion shaft *B* to revolve in the clockwise direction and thus swivel core *A* out of the die-cavity. The reverse movements occur when the movable die is returned to the stationary die, so as to again place core *A* in the die-cavity ready for the next operation.

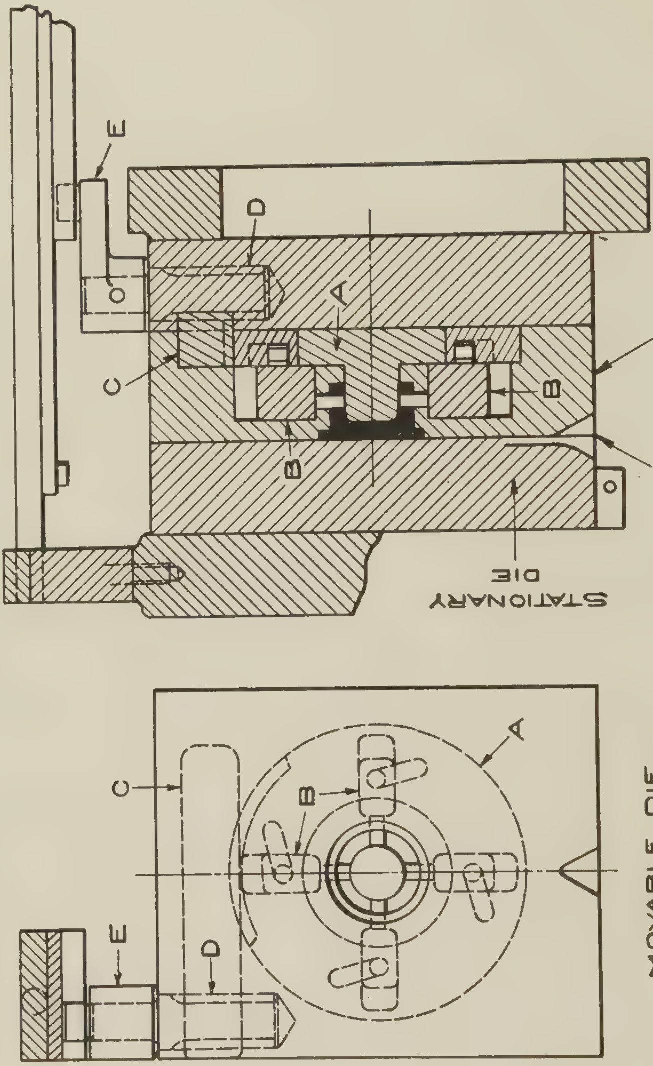


Fig. 19. Mechanism in which a Rotating Disk with Cam Slots Simultaneously Operates Cores in Four Different Directions

Revolving-Disk Method of Actuating Sliding Cores—Fig. 19.— When a series of cores must be operated in different directions, a revolving disk *A* may sometimes be employed to simultaneously actuate all of the cores with one mechanism. Disk *A* is provided with a series of cam slots which are engaged by rollers attached to four core-holders *B*. Gear teeth machined along the periphery of the disk are engaged by rack teeth cut on the bottom of slide *C*. The same slide has a second set of rack teeth machined on one side which are engaged by pinion *D*. This pinion is revolved as a roller on the end of lever *E* follows a cam path formed by bars mounted on top of the machine.

When the movable die withdraws from the stationary die at the end of each operation, slide *C* is pulled toward the left by the rotation of pinion *D* and a partial revolution is imparted to disk *A*. This movement of the disk causes the cam slots to act upon the rollers of core-holders *B* with the result that one of the cores is pulled upward, another to the right, the third downward, and the fourth to the left. With the return of the movable die against the stationary die, disk *A* is, of course, revolved in the opposite direction and all four cores are returned into the die-cavities as illustrated.

Two Core-Operating Disks Actuated by a Single Sliding Rack—Fig. 20.— Two revolving disks of the type illustrated in Fig. 19 can be actuated by a single sliding rack *A*, Fig. 20, for operating sliding cores into and out of two die-cavities. The diagram shows an arrangement for simultaneously operating eight cores in two cavities.

The teeth on opposite sides of sliding rack *A* engage teeth provided around the periphery of two disks *B*. When the movable die recedes from the stationary die at the end of each operation, the sliding rack *A* is pulled upward through the action of plate *C* as a roller attached to this plate follows a cam path provided by bars mounted on top of the

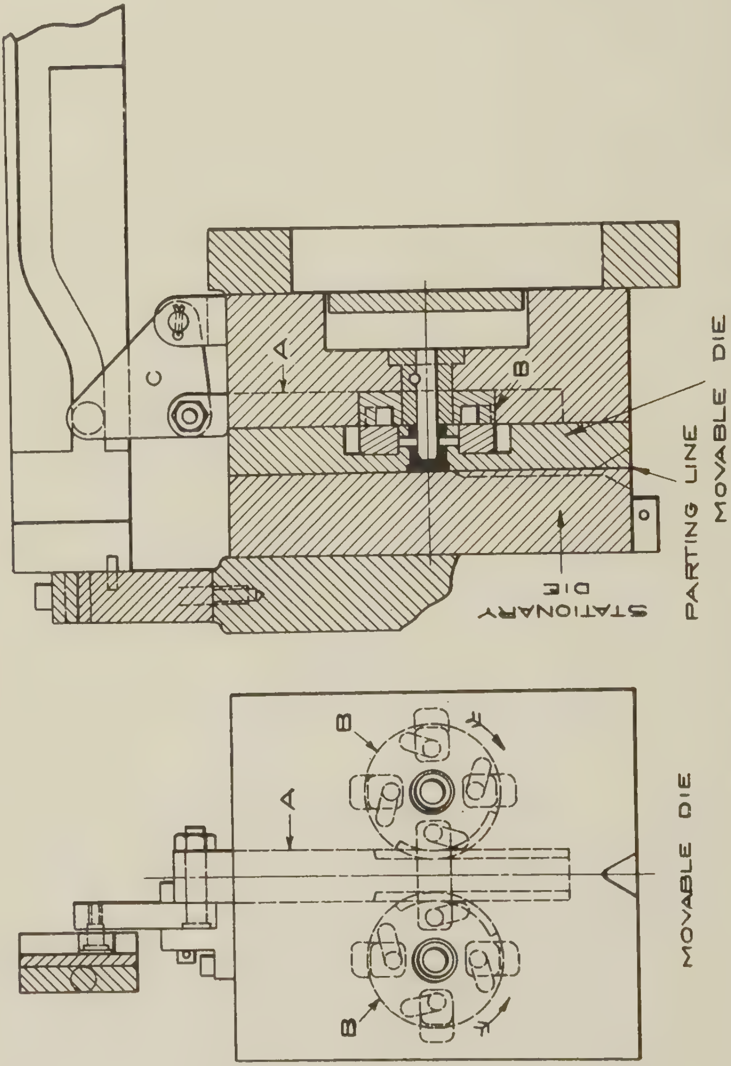


Fig. 20. Two or More Core-operating Disks Can Be Actuated by a Single Rack

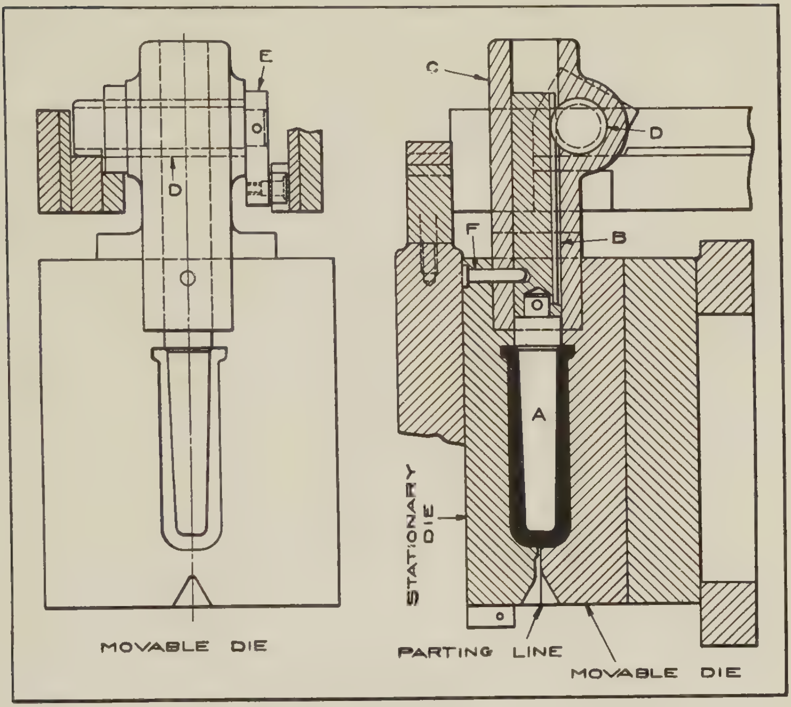


Fig. 21. Rack-and-Pinion Method of Operating Long Vertical Cores

machine. The upward movement of the sliding rack causes both disks *B* to make a partial revolution, one clockwise and the other counter-clockwise. This movement of the disks causes all of the cores to be withdrawn from the die-cavities in the manner explained in connection with Fig. 19. The cores are returned into the die-cavities when the movements of the mechanism are reversed with the return of the movable die to the stationary die.

Mechanism for Operating Long Vertical Cores.—Fig. 21.— When a long sliding core is positioned vertically in a die-cavity, the required core movement can sometimes be obtained by applying the rack-and-pinion principle as shown in Fig. 21. Core *A* is attached to a slide *B* which is contained in a holder *C* mounted on the face of the movable die. Rack teeth machined on the back of slide *B* are engaged by a pinion shaft *D* which is mounted in bearings of holder *C*. Fastened to one end of the pinion shaft is a lever arm *E* which is provided with a roller that engages a cam path formed by bars mounted on top of the machine.

When the movable die withdraws from the stationary die at the end of each operation, a partial revolution is imparted to pinion shaft *D* as the roller of lever *E* follows the cam path. With this movement of the pinion, slide *B* is pulled upward and, of course, core *A* is withdrawn from the die. The reverse movement of the core occurs when the movable die returns to the casting position. A large movement can be imparted to cores by employing this type of mechanism as there is practically no limit to the distance that slide *B* may be extended above the die.

Accurate positioning of core *A* in the die-cavity for each operation is insured by pin *F* which is mounted on the stationary die to engage a hole in slide *B* each time that the movable die is closed against the stationary die. As a matter of fact, with this arrangement the movable die cannot be closed until core *A* has been properly returned into the die-cavity.

Steels Used for Die-Casting Dies

The selection of the proper steel or steels for a die-casting die depends upon the metal to be die-cast, intricacy of the casting, and the quantity of castings to be produced or the probable life required of the die. Of these factors the most important is the metal from which the casting is to be produced, because its melting point alone determines whether the die can be constructed from ordinary machine steel, or whether high-grade alloy steels must be employed and heat-treated after machining.

Ordinary Machine Steel Satisfactory for Metals of Low Melting Points.—Dies designed for producing castings from zinc-, tin-, and lead-base metals can, as a general rule, be made from ordinary machine steel or cold-rolled steel, since the melting points of these base metals do not exceed 800 degrees F. If a zinc die-casting of complicated design, requiring a number of sliding cores, is to be produced or if the die must be made with sharp corners that will stand up for a long time, it is preferable to construct the die from an alloy steel such as steel *A*, *B*, *C*, *D*, *E*, *F*, or *G* in Table 1. Steels similar to types *C*, *D*, *E*, *F*, and *G* are particularly suited for long production runs of zinc castings since they have superior wear and heat checking resistance compared to other steels. These steels may be used in the hardened and tempered condition (418-477 Brinell) or they may be nitrided to provide a case 0.004 to 0.005 inch deep with a core hardness of 418-477 Brinell. Nitriding provides maximum resistance to the washing action of the molten casting metal and is an aid in producing castings with a high finish.

For dies having intricate impressions, particularly those with fine detail, the cavity is often produced by hobbing, that is, by forcing a hardened master, which has the same contour as the casting to be produced, into a soft steel block. Characteristic of steels that are suitable for hobbing, steels *L* and *M* are of low hardness in the annealed state and work-harden more slowly than non-hobbing steels.

Hobbed dies are usually put into service in the hardened and tempered condition or after a light carburizing treatment.

Dies for Aluminum and Magnesium Castings Must Possess High Heat-Resisting Qualities.—Aluminum - base alloys used in die-casting operations have a melting point up to about 1150 degrees F., and for this reason, dies for casting these base metals must be constructed of high-grade alloy steels and the steels must be heat-treated. Dies for casting aluminum are often made from alloy steels having the composition of types *C, D, E, F,* and *G* or of type *M* if the cavity is to be produced by hobbing.

Steels of types *C, D, E, F,* and *G* should be hardened and tempered to 418-477 Brinell or, if resistance to the washing action of molten aluminum is required, they should be nitrided to a depth of 0.004-0.005 inch. Steel *M* is particularly suited for dies which are to be hobbed. It hardens to 37-42 Rockwell C by air cooling or oil quenching. Dies in the hardened condition are often used for casting aluminum or magnesium on short runs. For longer runs the dies will stand more abuse if the surfaces are lightly carburized.

The particular requirements of a steel for die-casting aluminum-, magnesium- and copper-base alloys have been listed as follows:

(1) Machineability; (2) stability in heat-treatment; (3) resistance to heat checking; (4) resistance to deformation, battering, etc. (hardness) ; (5) resistance to cleavage cracking on sudden heating or cooling (toughness) ; (6) re-

sistance to the erosive and solvent actions of molten metal; (7) cleanliness and uniformity; (8) cost—productibility, forgeability, etc.; (9) ability to withstand elevated temperatures.

Failure from Heat Checking and Cleavage Cracking.—With practically all steels, the die life seems to be determined, as far as heat checking is concerned, by the initial hardness. Up to the point where insufficient toughness remains in the steel, it appears to be true that the harder the block, the longer it will stand up.

Apart from the relation between hardness and resistance to heat checking, a certain amount of hardness is required for service reasons. Dies are made up of moving parts—slides, cores, pins, etc.—and are usually hot when in operation. Therefore, all die parts must be hard enough to prevent excessive rubbing, scoring, and seizing of the parts. All parts should be hard enough to resist defacement or deformation resulting from the powerful closing action of die-casting machines, should stray pieces of metal become accidentally caught on the parting faces of the dies.

Cleavage cracking is not a serious difficulty with the chromium-vanadium steels, but it is serious with the chromium-tungsten steels. Cleavage cracking does not seem to have much relation to the hardness, but is more closely associated with the macrostructure.

Erosion and a solvent or soldering action of the molten metal are likely to occur at the gates of dies where the molten metal is at maximum temperature and is made to travel at high velocities across the die steel. The erosive action sometimes becomes severe when the molten metal impinges directly on a die surface. Resistance of the steel to a solvent action and to erosion is therefore important.

Cleanliness and Uniformity are Essential in Die Steels.—Cleanliness and uniformity are essential in a die steel because segregations and non-metallic inclusions serve as

Table 1. Nominal Compositions of Some Steels Used for Die-Casting Applications

Element	Letters Designating Different Steels												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Carbon......	0.30	0.35	0.35	0.40	0.40	0.40	0.35	0.35	0.42	0.28	0.35	0.08	0.10
Manganese...	0.75	0.70	....	....	....	0.35	0.60	....	....	....	0.30	....	0.30
Silicon.......	0.50	0.25	....	....	1.05	1.10	1.00	....	....	....	0.30	....	0.25
Chromium...	0.80	1.00	5.00	5.25	5.00	5.00	5.00	2.75	3.50	3.25	3.50	2.00	5.00
Vanadium...	....	0.20	....	0.90	1.10	0.90	0.25	0.30	0.30	0.25	0.40	....	0.25
Tungsten....	....	....	1.55	....	....	....	1.40	9.00	14.00	9.00	9.00	....	....
Molybdenum.	0.25	....	1.65	1.20	1.35	1.35	1.55	....	....	....	....	....	0.90

Table 2. Typical Applications for Steels Listed in Table 1

Alloy to be Cast	Life Required of Die Components	Steels Commonly Used			
		Dies	Cores and Slides	Ejector Pins	Holder Blocks
Lead or tin............	Short, medium, or long	A,B,L[1],M[1]	A,B	C,D,E,F,G	A,B
Zinc..................	Short or medium......	A,B,L[1],M[1]	A,B	C,D,E,F,G	A,B
	Long.................	C,D,E,F,G,M[1]	C,D,E,F,G	C,D,E,F,G	A,B,C,D,E,F,G
Aluminum or Magnesium	Short, medium, or long	C,D,E,F,G,M[1]	C,D,E,F,G	C,D,E,F,G	A[2],B[2],C,D,E,F,G
Copper...............	Short.................	H,I,J,K	H,I,J,K	H,J,K	A[3]B[3]
	Medium..............	H,I,J,K	H,I,J,K	H,J,K	C[3],D[3],E[3],F[3],G[3]
	Long.................	H,I,J,K	H,I,J,K	H,J,K	H,J,K

[1] Steels *L* and *M* are used for dies which are to be produced by hobbing. [2] For long production, gate-former inserts of steels *C*, *D*, *E*, *F* or *G* are used. [3] Used with gate-former inserts of steels *H*, *I*, *J*, or *K*.

starting points for thermal fatigue failures and cleavage cracking. Segregations appearing as hard spots will also cause difficulties in die-sinking. There must be no internal seams, slits, cracks, or other defects at or near the base of a die impression after the greater part of the die-sinking has been done.

Die-casting dies are subject to temperatures ranging from room temperature or lower (as when water is used for cooling the dies) up to 2300 degrees F. (in casting aluminum bronze). Small uncooled parts of dies near the gate, which are almost completely surrounded by molten metal, often become heated almost to the temperature of the incoming metal. In many cases, the surface of the die steel becomes red hot before the body of the die can conduct the heat away. For this reason, red hardness seems to be a desirable property for a die-casting die steel that is to be used in casting alloys of a high melting point.

Steels for Brass Die-Casting Dies.—The higher temperatures required in die-casting copper base or brass alloys make it necessary to use different grades of steel than are required for aluminum die-castings. The steels, of course, must be heat treated. Steels that have proved satisfactory for copper base alloys are listed at *H*, *I*, *J*, and *K* in Table 1. The main difference between these steels and those used for making dies for casting aluminum is their greater tungsten content. The higher tungsten content of these steels results in greater red hardness and wear resistance. Even with these steels, however, it is necessary to dress the dies from time to time to insure a smooth finish on the castings because even the best steel that is available at present is subject to heat checking.

Heat-Treatment of Die Steels.—Die-casting die steels are usually machined in a soft annealed condition and heat-treated after finish-machining. The temperature and length of time required for the various steps in heat-treatment depend on the type of steel and the size and intricacy of the piece being treated. The standard procedure in heat-treating most of the hot-work die steels starts with slow cooling after forging. After being cooled, these steels are annealed, the temperature for the hot-work steels being about 1600 degrees F. Tungsten steel for casting copper-base alloys is annealed immediately after forging instead of being first normalized. This steel is annealed at a temperature of between 1600 and 1650 degrees F. The cooling is retarded at around 1450 degrees F. to obtain the desired structure. The normalizing and annealing operations are generally performed at the steel mill; hence the user is not particularly concerned with the details of the two treatments.

The high temperatures involved in heat-treating die steels make it necessary to protect the surfaces during the heat-treatment. This is customarily done by packing the dies in cast-iron chips or aluminum-oxide pellets or heating them in controlled-atmosphere furnaces.

In the hardening operation, die steels are heated to temperatures ranging from 1600 to 2250 degrees F., depending upon the particular type of steel. They are then quenched in oil or cooled in still air. Steels for copper-base alloys are pre-heated to a temperature of from 1500 to 1550 degrees F. before hardening. After hardening, die steels are tempered by practices that have been developed especially for each type of steel. The exact temperature to be used and the procedure to be followed in heat-treating die steels are generally supplied by the manufacturers.

Table 2 indicates the types of steel that are commonly used to produce the principal components of die-casting dies. Table 1 gives the nominal compositions of these steels.

Die-Casting with Semi-Automatic Machines

Die-casting is sometimes thought of as a process that requires automatic machines involving a comparatively high initial investment. Such an impression is decidedly wrong, as will be apparent from Fig. 1, which shows a number of dies made for die-casting various parts in small hand-actuated semi-automatic machines. These machines were originally intended for use under conditions of limited production, but they have proved speedy enough to meet the production requirements on certain parts for large automobile plants. Beneath the die sets in Fig. 1 are shown the castings produced by them. The dies to be described were designed specifically for use on smaller machines of the semi-automatic type.

Operation of Semi-Automatic Machine.—In die-casting with the "Kippcaster" machine, the operator revolves a spoked wheel counter-clockwise to close the movable half of the die against the stationary member. At the same time, the metal pot and gooseneck are automatically rocked forward into the casting position. The operator then steps on a foot-pedal to lock a toggle which holds the dies closed during the operation. An air-valve lever is next moved to actuate the piston of an air cylinder, which causes a plunger to move downward in the melting pot and force metal into the die-cavity.

After the short interval required for casting, the air-valve handle is pulled toward the operator, so as to withdraw the metal-forcing plunger to its upper position. A

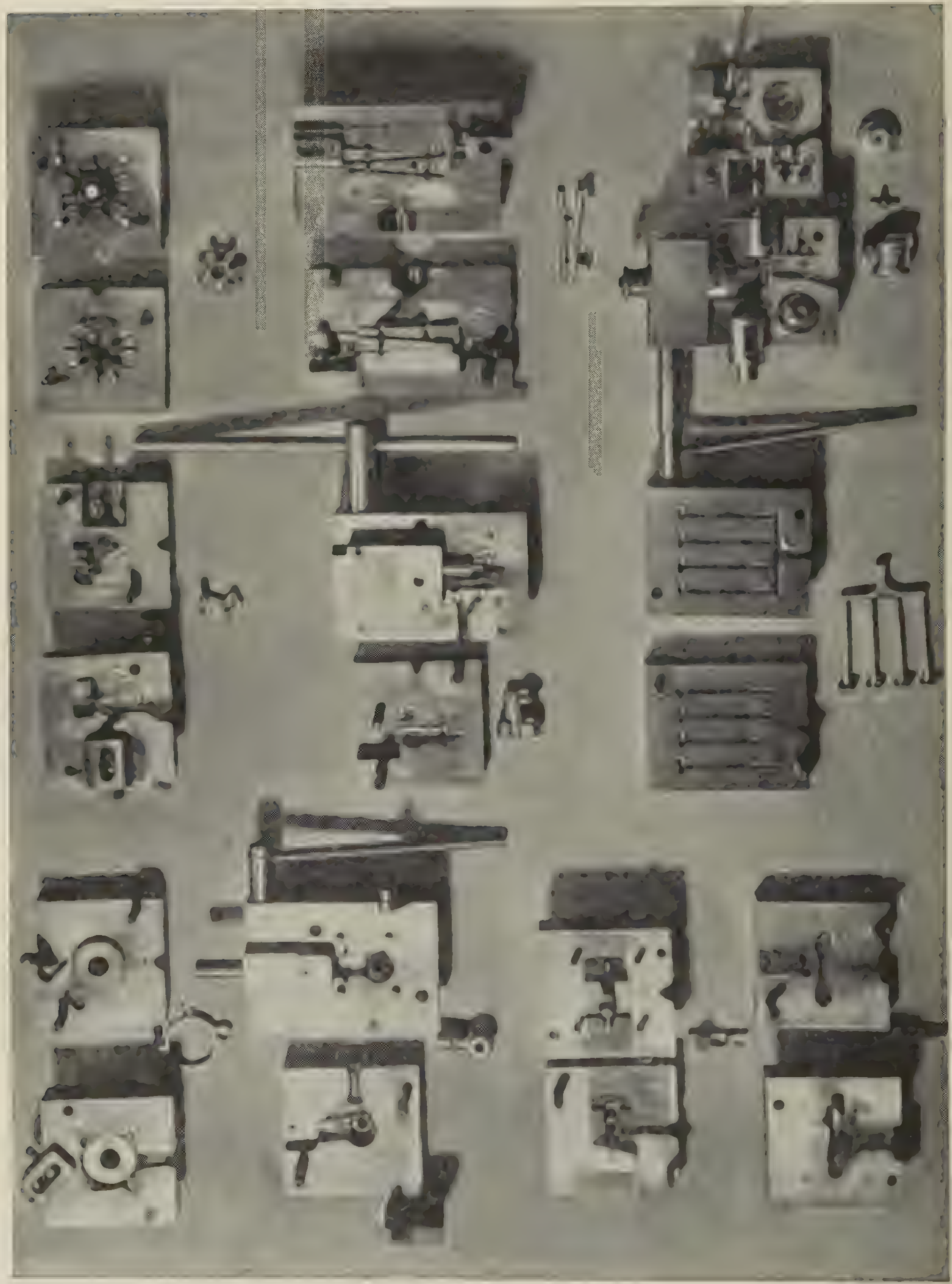


Fig. 1. Dies that Indicate the Possibilities of Die-casting Parts Singly and in Multiple in Small Semi-automatic Machines

second foot-pedal is then depressed, unlocking the die halves and partially opening them, after which the spoked wheel is turned clockwise to complete the opening of the die and eject the casting. The metal pot and gooseneck are rocked into their idle position simultaneously with the opening of the die.

Dies 6 inches square by 3 inches thick are standard for these machines, but the die dimensions can be varied considerably, depending upon the pressure area of the cavity and the weight of the casting. The die investment is relatively small, and the dies can be readily interchanged to suit production requirements. From four to ten "shots" can be made a minute with these machines, and several pieces can often be cast with each "shot." Castings weighing up to a pound have been cast by the machines referred to.

Sixteen Hundred Die-Castings an Hour with Semi-Automatic Equipment.—Lead battery bushings such as shown in Fig. 2, which are about 7/8 inch outside diameter by 7/8 inch long, are cast at an unusually high rate of production by means of the dies shown in Fig. 3. Eight pieces are cast at a time and four "shots" are averaged a minute. Figuring on an hour of only 50 minutes, the production per hour is 1600 pieces. These bushings were formerly hand-poured in gravity molds. Not only has the rate of production been increased tremendously by die-casting them, but the previous high scrap loss due to defective pieces has also been eliminated.

The arrangement of the eight cavities will be understood from the left-hand view, which illustrates the movable die. The parting line of the die is stepped rather than straight. Its path is indicated by letters *X* in the right-hand view. One half of each bushing is cast in the stationary die, and the other half in the movable die. The molten metal is forced into the die through sprue *A*, from which two leaders *Z* run to each of the eight cavities. At the point where the metal actually enters the cavities, these leaders are 7/64 inch wide by 1/32 inch deep.

A hole 9/16 inch in diameter is formed in the lead bushings by cores *B*. These cores are automatically pulled from the castings when the movable die is withdrawn from the stationary member at the end of an operation. The movement of cores *B* is effected as rollers *C*, attached to links *D*, follow the cam path *Y* on bars fastened to one side of the stationary die.

The ends of links *D* opposite the roller ends are mounted on shafts *E*, which are provided with spur-gear teeth for the greater part of their length. The teeth of these pinion shafts engage rack teeth on slides *F* to which cores *B* are fastened. Hence, as shafts *E* are swiveled on their axes by the movements of links *D*, cores *B* are operated vertically in the movable die. Links *D* swing about 90 degrees to effect a 15/16-inch vertical movement of the cores. Eight pins *P*, mounted in the stationary die, lock slides *F* and their cores securely in position vertically when the movable die is in the closed position.

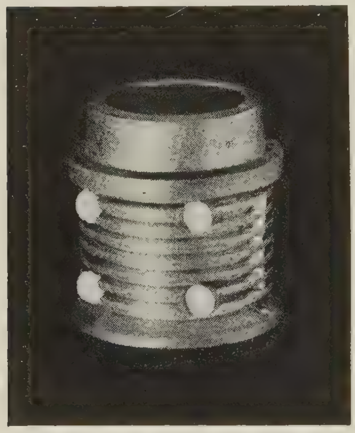


Fig. 2. Lead Bushing Die-cast at the Rate of 1600 an Hour

An unusual feature of this set of dies is a slide *G* that shears off the sprue from each piece, and thus eliminates a separate trimming operation. Slide *G* closes one-half of one end of each cavity and it contains the shallow runners through which the molten metal is forced into the cavities.

The slide is held to the face of the moving die by means of two hardened gibs. An angular hole near the right-hand end of the slide is engaged by a pin which is fixed in the

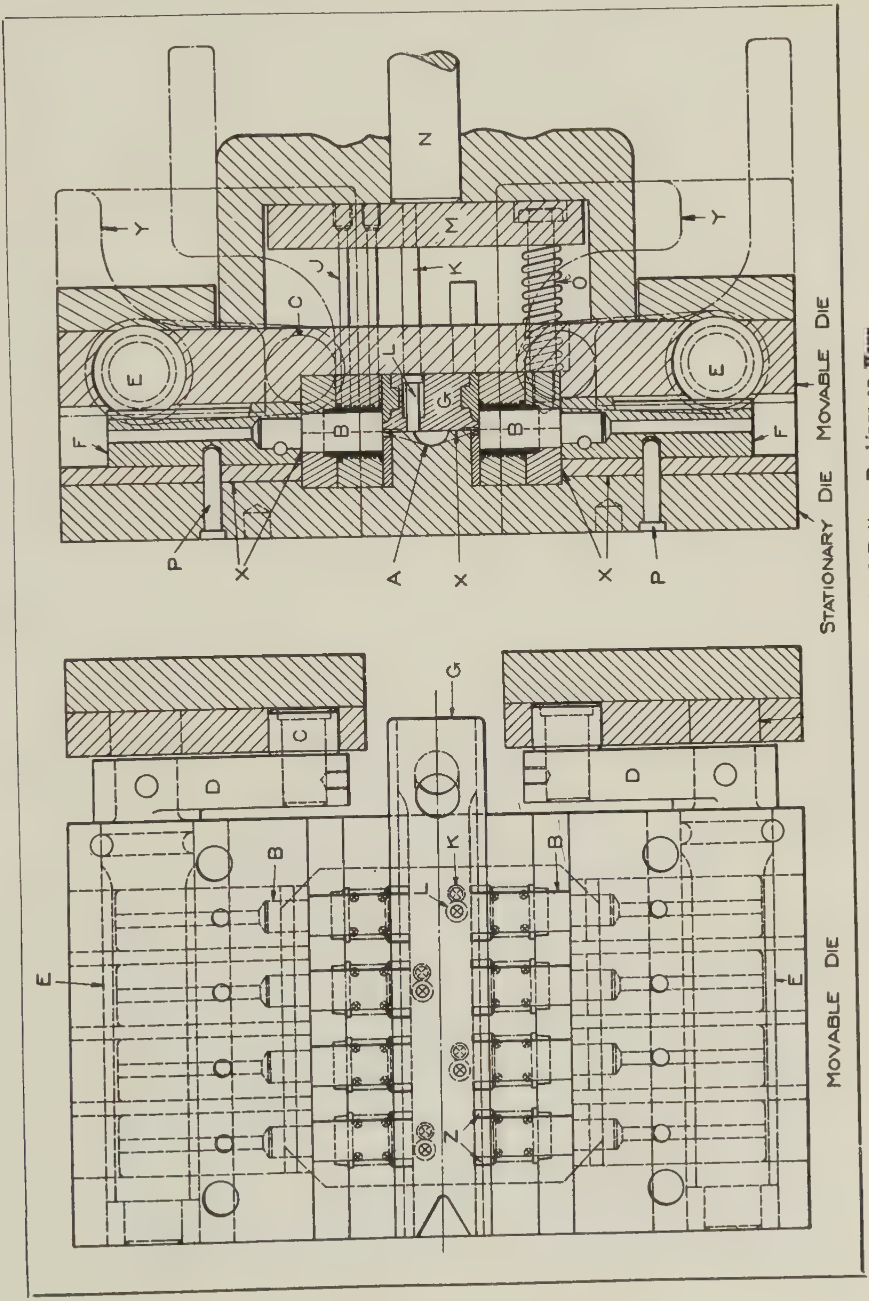


Fig. 3. Set of Dies that Produces 1600 Lead Battery Bushings an Hour

stationary die. When the movable die is withdrawn from the stationary member, the slide is pulled sidewise 1/4 inch. This sidewise movement shears the metal in the sprues that lead to the different die-cavities. Slide *G* is provided with long hardened steel inserts where the shearing action occurs, and these inserts are made with fine teeth to facilitate the shearing.

Forty Ejecting-Pins Remove the Work Pieces and the Sprue Metal.—Four long slender pins *J*, Fig. 3, are provided for ejecting each piece from its cavity, and in addition, there are four pins *K* that actuate the shorter pins *L* for forcing the sprue metal from the die. Pins *L* are necessarily made separate from pins *K* because, being mounted in the sprue cutter, they must be moved horizontally with it. When the movable die is closed against the stationary member for a casting operation, these pins are displaced relative to each other, as may be seen in the left-hand view, but when the sprue cutter has moved to the right, the pins are axially in line for the ejecting action. The ejector-pins are indicated by crossed lines in the left-hand view.

All of the ejecting-pins are brought into play when plate *M* comes in contact with rod *N* as the movable die approaches the end of its opening stroke, rod *N* being held fixed on the machine. Then, as the movable die continues its stroke for another half inch, plate *M* and the ejecting pins are held stationary, forcing the castings and the sprue from the die.

Plate *M* is attached to the movable die by six studs *O*. Coil springs surrounding these studs return plate *M* and its ejector-pins to the position shown when the movable die is again advanced to the stationary member. Four pilot-pins on the stationary die enter holes in the face of the movable die to insure proper alignment for each operation.

Air pressure of 80 to 100 pounds per square inch is applied directly by the air cylinder to force the plunger of the gooseneck into the molten metal for each operation. This

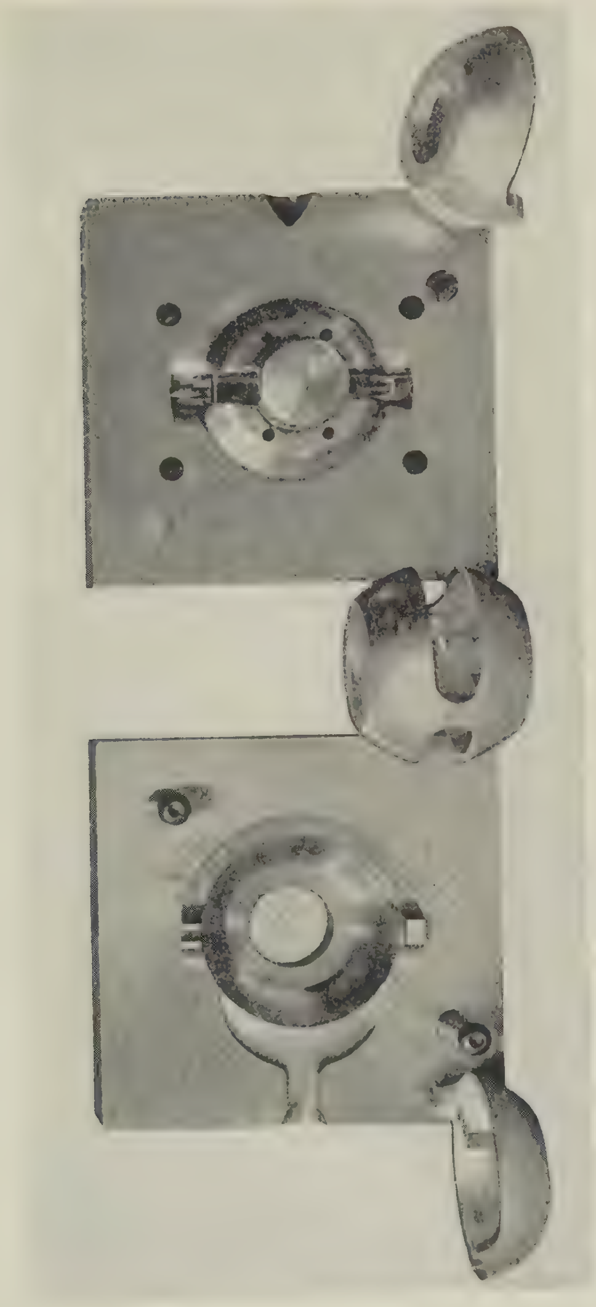


Fig. 4. Dies Used to Produce Bowl-shaped Parts, Assembled in Pairs to Obtain a Universal Ball

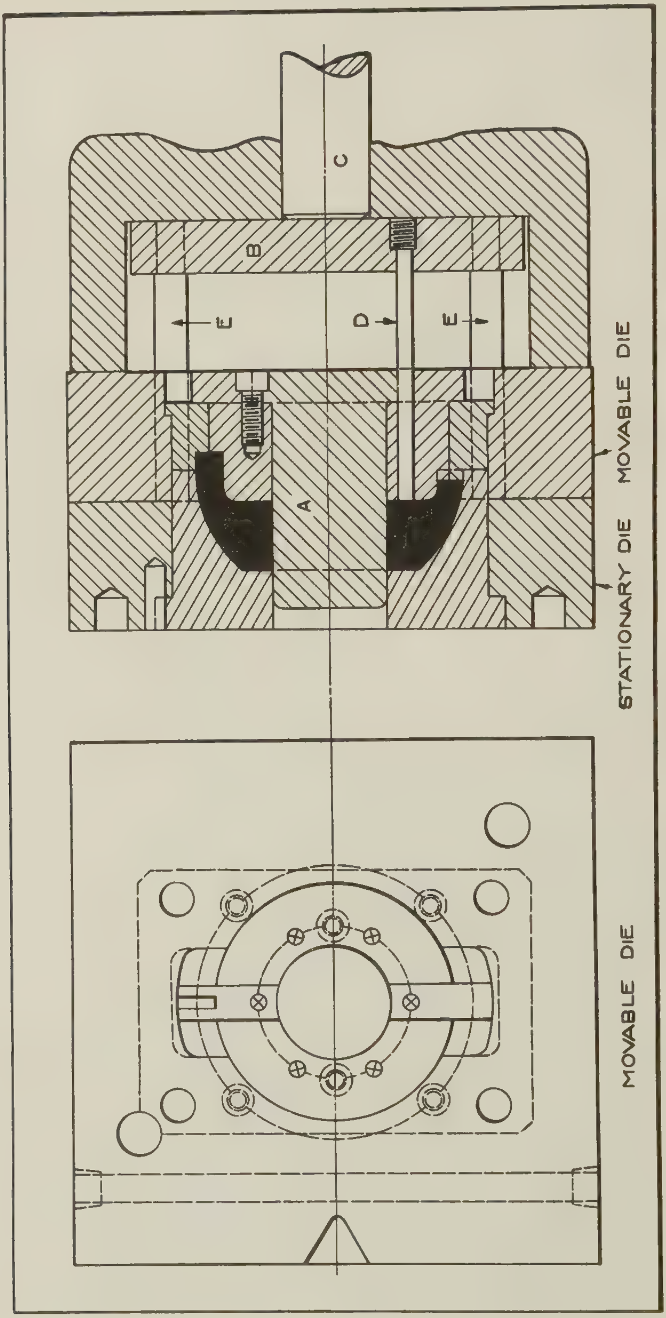


Fig. 5. Drawing that Shows the Constructional Features of the Dies Illustrated in Fig. 4

creates a pressure of approximately 600 pounds on the molten metal where it enters the various cavities. The melting pot is held at a temperature of 750 degrees F. The various pieces that make up the cavities of these dies are made from a nickel-chromium steel. Dies of this type last year in and year out, without replacement. One set has been in continuous operation for over five years.

Spherical Segment-Shaped Zinc Die-Castings.—The universal ball seen in the center of Fig. 4 is made up of two identical pieces, which are cast in the set of dies shown in the same illustration. Both halves of the ball have raised lugs on opposite sides. On the top of one lug there is a rounded tongue, while the top of the other lug is provided with a groove to fit this lug. The two halves can be easily assembled by placing the tongue of one piece in the groove of the other.

The die shown at the left is mounted stationary on the machine, while the die at the right is moved to and from the stationary member by hand. These dies are arranged with a gate at the side instead of at the bottom, as is the case with all the dies made by the Madison-Kipp Corporation for use on the larger fully automatic machines built by the concern. The die-cavity, except for the lugs, is entirely in the stationary member, as will be seen from Figs. 4 and 5, and all cores are mounted on the movable member.

During the withdrawal of the movable die, upon the completion of an operation, the casting remains on core *A*, Fig. 5, until plate *B* strikes a fixed rod *C*. Plate *B* is then held stationary while the die movement is completed. Attached to plate *B* are six long slender pins *D*, which ordinarily extend through the movable die and are flush with the die-cavity. However, when the movement of plate *B* is stopped, these pins enter the die-cavity and eject the casting. They are again brought flush with the bottom of the cavity when the movable die is closed against the sta-

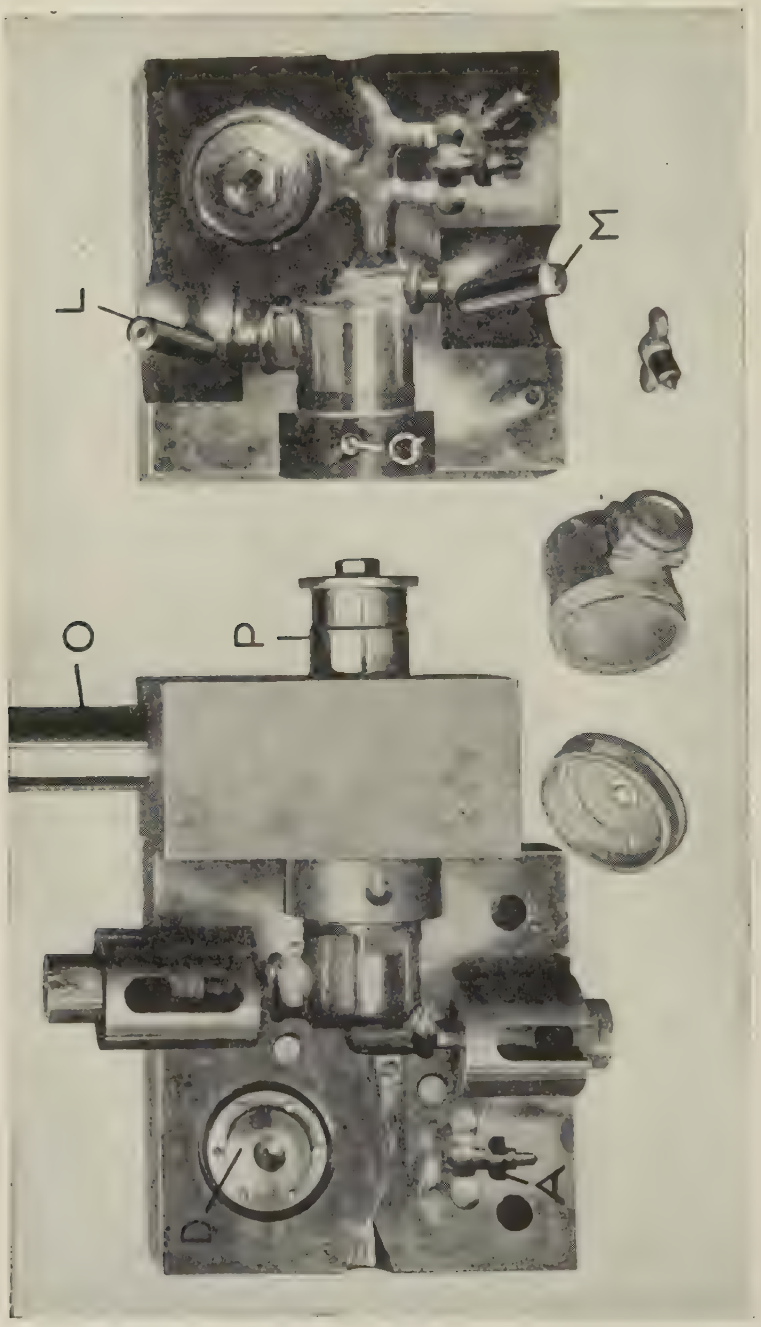


Fig. 6. Dies Used for Producing Three Different Die-castings at the Same Time

tionary member for the next operation. This occurs as four pins *E* come in contact with the face of the stationary die and return plate *B* to the position illustrated. Three "shots" are averaged per minute with this set of dies. The casting is made of zinc, and is approximately 3 inches maximum diameter. The generous gate provided can be clearly seen on the stationary die in Fig. 4. These dies should last long enough to produce 500,000 parts or more.

Casting Three Parts of Different Shape in One Die.— Dies are sometimes designed to cast several different pieces simultaneously in cases where the production required for any one piece is comparatively limited. Dies of this type are illustrated in Fig. 6. The movable die is shown at the left and the stationary die at the right. These dies cast the bowl-shaped fitting seen at the left in Fig. 7, the fitting cover at the right, and the threaded thumb-screw shown between these two parts.

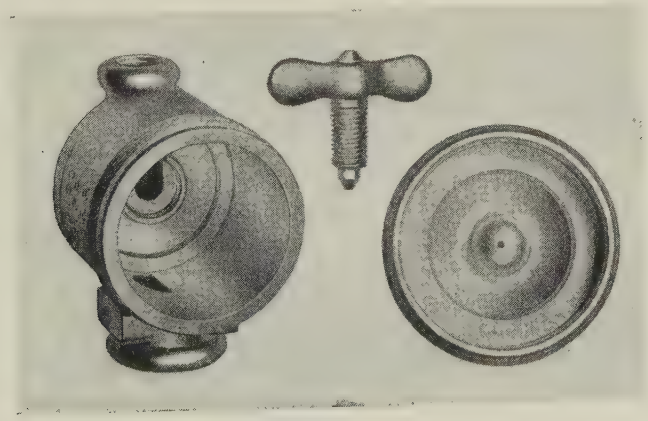


Fig. 7. The Three Parts Produced in Each Operation Performed with the Dies Illustrated in Fig. 6

The interesting features of this set of dies will be seen by reference to the sectional views, Fig. 8. The threads of the thumb-screw are produced by a steel insert which is placed in an opening in the face of the movable die when

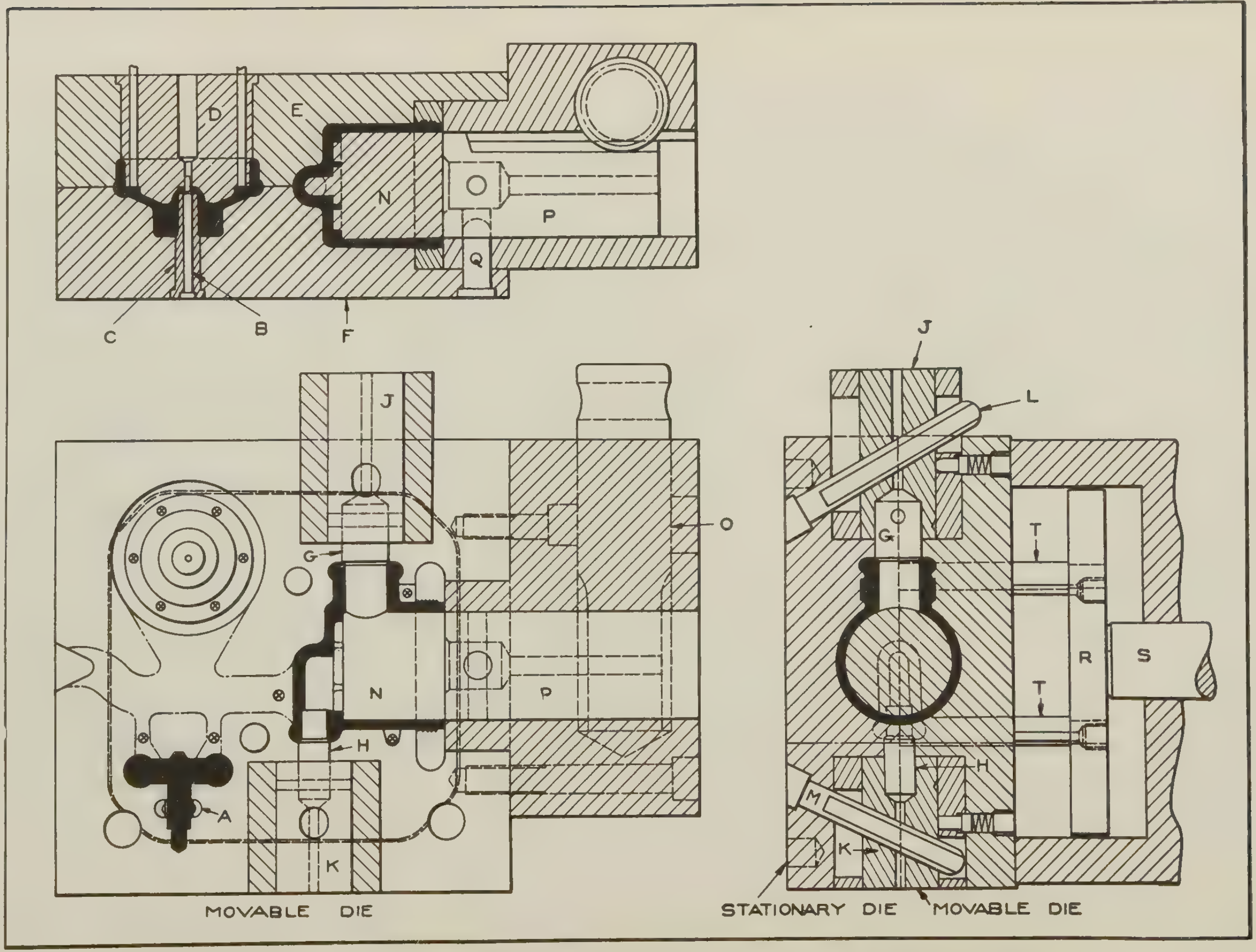


Fig. 8. Details of Construction of Dies Shown in Fig. 6

the dies are open, and is held in place by spring clips *A* on a block which is fastened to the movable die. One half of the thumb-screw is formed in the stationary die and the other half in the movable member.

The fitting cover is formed as shown in the upper view. A hole 1/16 inch in diameter is produced by core *B*, which is mounted in the center of the larger core *C* of the stationary die. The internal surfaces of the cover are shaped by core *D* of the movable die, while the outside surfaces are produced by die-blocks *E* and *F* of the movable and stationary dies, respectively. It will be noted that core *B* extends into a close fitting hole in core *D*, thus preventing the formation of flash around the 1/16-inch hole. The threads on the fitting cover are cut by machine.

The fitting itself is of such design as to require three moving cores. Cores *G* and *H* are automatically pulled up and down as the movable die is withdrawn from the stationary die, due to the action of core-holders *J* and *K* sliding on pins *L* and *M*. Since both of these pins project at an angle from the face of the stationary die, they produce vertical movements of core-holders *J* and *K*, which are, of course, mounted on the movable die. The two core-holders are retained in the raised and lowered positions by spring detents.

The large core *N* which shapes the inside of the bowl is withdrawn from the finished casting by turning shaft *O* with a long handle that fits in the hole provided near the upper end. Pinion teeth on shaft *O* engage rack teeth on the back of core-holder *P* and thus move the holder and core *N* laterally when shaft *O* is turned. Pin *Q*, Fig. 6, on the stationary die enters a hole in holder *P* when the die is closed, so as to hold core *N*, Fig. 8, firmly as the molten metal is "shot" into the die-cavity.

Plate *R* carries eleven ejector-pins, which remove the castings from the movable die when the plate strikes rod *S* during the opening movement. Pins *T* push plate *R* back

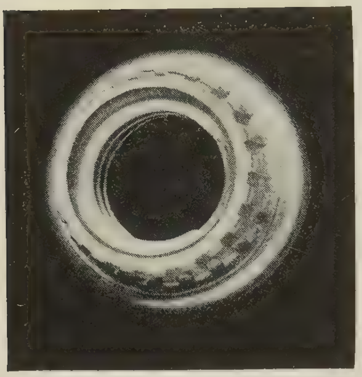


Fig. 9. Lead Battery Nut Die-cast with an Internal Square Thread

into the position shown when the movable die is closed against the stationary member. Two "shots" are averaged a minute with these dies, which means a production of 100 an hour of each of the three pieces. These castings are made of zinc. The dies should produce 500,000 parts before they need to be replaced.

Lead Battery Nuts Having Double Internal Thread.—Lead battery nuts of the type shown in Fig. 9 are cast with a double, square, internal thread 7/8 inch in diameter. There are 3 1/2 threads per inch. The maximum diameter of the part is 1 5/8 inches. The threads are produced so accurately that the nuts are ready for use as they come from the dies. Four nuts are cast at a time with the die

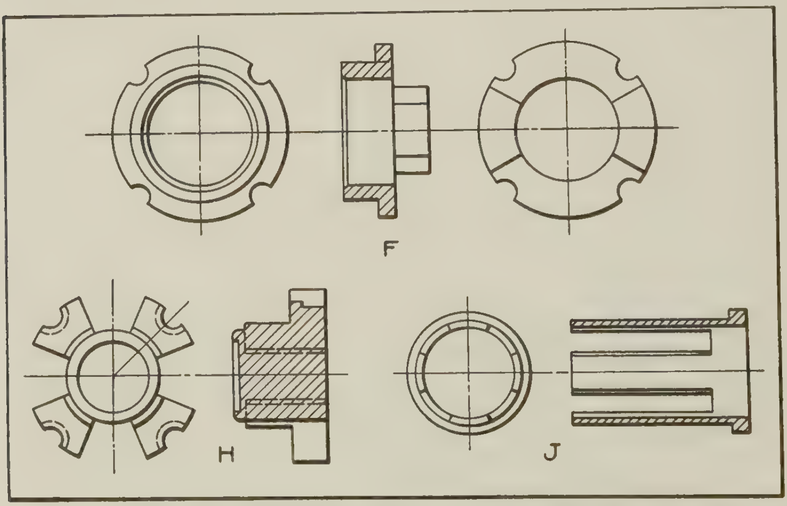


Fig. 10. Details that Illustrate the Method of Ejecting the Lead Nuts from the Set of Dies Illustrated in Fig. 11

set illustrated in Fig. 11. Only one of the die-cavities is shown in the left-hand view, which shows the face of the movable die. However, the center lines of the other three cavities are indicated.

An interesting feature of these dies is that the four externally threaded cores *A* which produce the internal threads in the nuts must be unscrewed from the work-pieces before the movable die can be withdrawn from the stationary die at the end of an operation. The unscrewing of these threaded cores is accomplished by turning a rod on the left-hand end of shaft *B*. This shaft is mounted in the center of the stationary die. When shaft *B* is turned, spur-gear teeth on the right-hand end of the shaft revolve four pinions *C*, each one of which is keyed to a shaft *D*. The shank of each threaded core *A* fits into the end of one of these shafts *D* so that the cores revolve with the shafts when pinion-shaft *B* is rotated.

Lead-screw threads are provided on shafts *D*, as indicated at *X*. These threads engage corresponding threads in the die-block *E*. Hence, as each shaft *D* and the corresponding core *A* are revolved, they are also moved laterally to the left, thus withdrawing the core from the work. In positioning the cores prior to the casting operation, shaft *B* is merely turned in the reverse direction. A washer *G* on the left-hand end of shaft *D* controls the casting position of the threaded core *A*.

Part *F* forms a bevel on the outer end of each nut, while a flanged bushing *H* forms a filleted depression in the same end. Outside of the portion of part *H* that forms this depression, there are four dovetailed slots, as seen in the detailed drawing of this part in Fig. 10. These slots permit fingers on sleeve *J* to come in contact with the work and eject it. Part *F* completely encloses sleeve *J* and bushing *H*. The four ejecting sleeves *J* are operated when plate *K* is stopped by fixed rod *L* during the withdrawal of the movable die from the stationary member. As the die completes

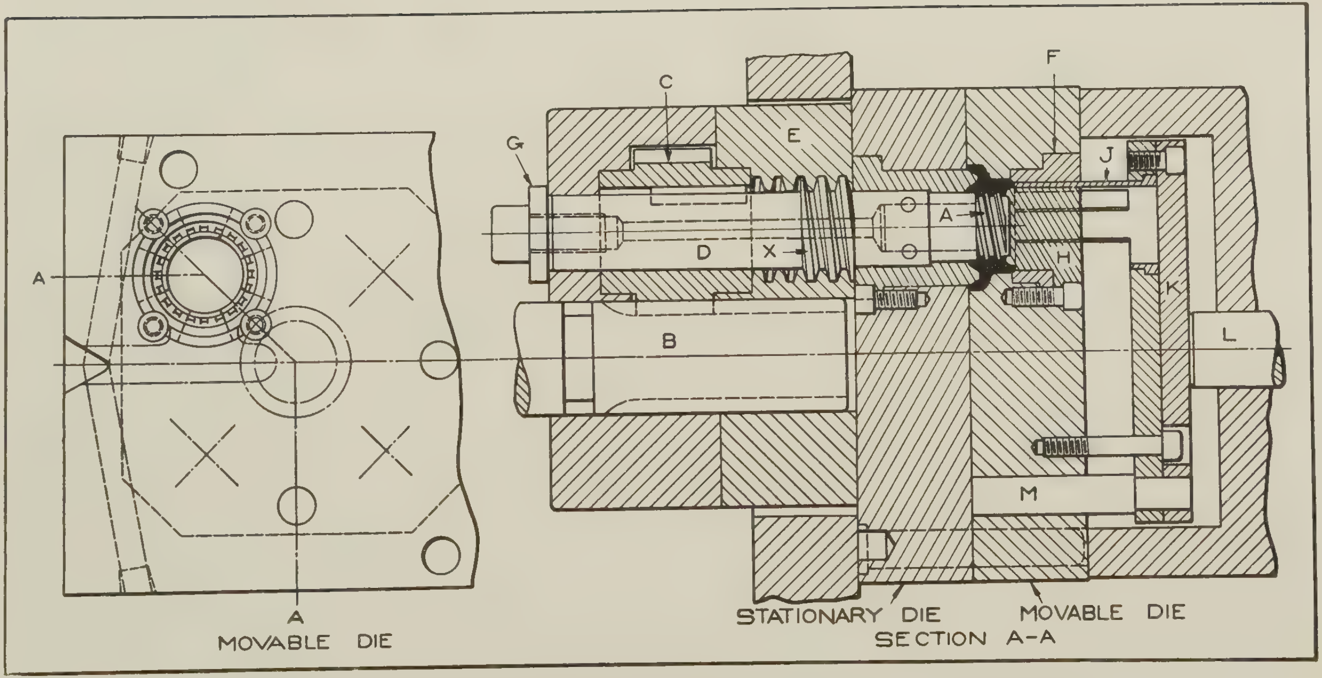


Fig. 11. Four Shafts D with Lead-screws Withdraw the Cores Used in Casting the Threaded Nut Shown in Fig. 9

its movement, the fingers of each sleeve *J* advance in the slots of part *H* and push the casting from the die-cavity. Four pins *M* come in contact with the face of the stationary die when the movable die is again closed, and return plate *K* and the ejecting sleeves to the positions shown.

About two "shots" can be made a minute with this set of dies. Based on a fifty-minute working hour, this means 400 castings an hour. The melting pot is held at a temperature of about 750 degrees *F*. Channels are provided across the gate side of both the movable and stationary dies for circulating cooling water.

Lead Terminals Cast on Insulated Wire Cables.— The dies illustrated in Fig. 12 were designed for casting lead terminals on the ends of insulated wire cable. Two cables are inserted in the dies from the right-hand side for each operation. Spring clips on a bracket attached to the movable die member hold the cables in place during the operation.

For reinforcement purposes, steel wires of the shape shown at *X* are cast in the lead terminals. These wires are slipped over the cores *B* of the movable die when it is in the open position, and they are properly seated by cores *C*. Each core *C* is attached to a slide *D*, which has rack teeth on the back, as seen in the right-hand view. The rack teeth are engaged by the pinion-shafts *E*, which are turned by hand to move cores *C*. Slides *D* are dovetailed to the face of the movable die. They are locked in the casting position by pins *F* of the stationary die. Spring detent *J* holds the bottom slide from falling from the face of the movable die.

Ejection of the casting is effected by a series of pins on plate *G*, which extend through the die members to the cavities. These ejector-pins are brought into operation when plate *G* strikes rod *H* during the opening movement of the die. Four coil springs surrounding the studs attached to plate *G* force the plates and the ejector-pins into the posi-

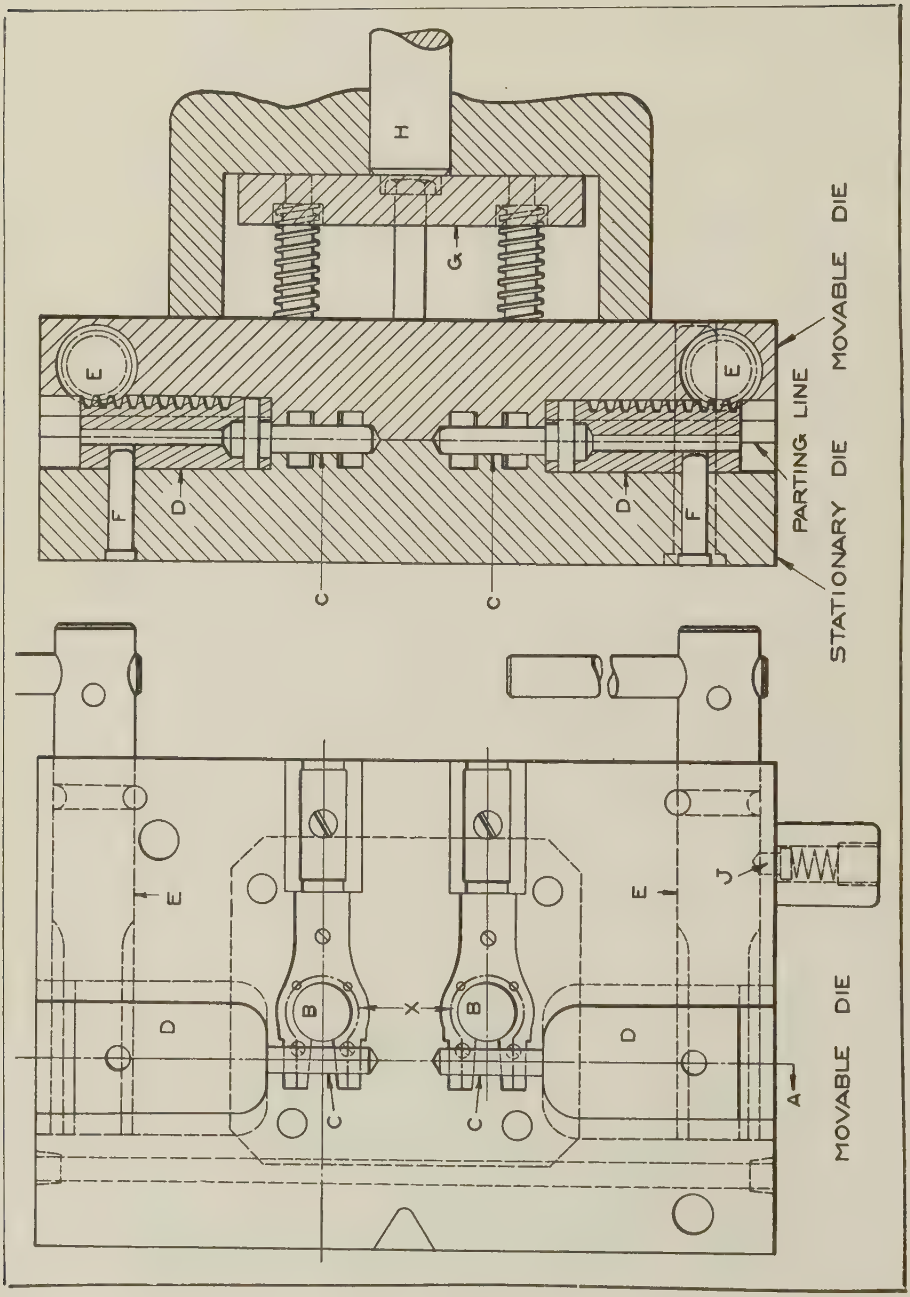


Fig. 12. Dies which Cast Lead Terminals on Ends of Insulated Wire Cables

tions shown when the dies are closed again. Cores *B* produce holes through the solid portion of the lead terminals. Production on this operation averages one "shot" a minute, or 100 lead terminals per fifty-minute hour. The temperature of the melting pot is maintained at about 750 degrees F.

Die with Irregular Parting Line.—In casting parts from an aluminum alloy, the melting pot must be held at a temperature of approximately 1300 degrees F. Such a high temperature requires adequate cooling provisions in order to prevent the dies from becoming excessively hot. In Figs. 13 and 14 are shown the dies designed for producing the hair-clipper handle shown in the upper part of Fig. 15. Holes *Y*, Fig. 14, permit the circulation of sufficient cooling water across the die members in the vicinity of the sprue hole to enable these aluminum parts to be cast successfully.

The parting line of these dies is of particular interest because of its irregularity, which is necessitated by the angularity of the clipper handle. Core *D* is automatically withdrawn from the casting when the movable die is drawn away from the stationary die, on account of the engagement of pin *F* on the stationary die with the angular hole in holder *E*. The vertical movement of core *D* and its holder is about 1/2 inch. Holder *E* is held to the face of the movable die by means of a plate. Spring detent *H* retains part *E* in the raised position when the dies are opened.

Ejector-Pins Contact with Flash on Casting.—Ejector-pins attached to plate *J* (Fig. 14) force the casting from the movable die during its withdrawing stroke as the plate *J* strikes rod *K*. However, the ejector-pins do not come in direct contact with the casting. Instead, they are positioned to contact with the flash that is allowed to form at several points along the handle. The position of these ejector-pins can be observed in the left-hand view, in which the ejector-

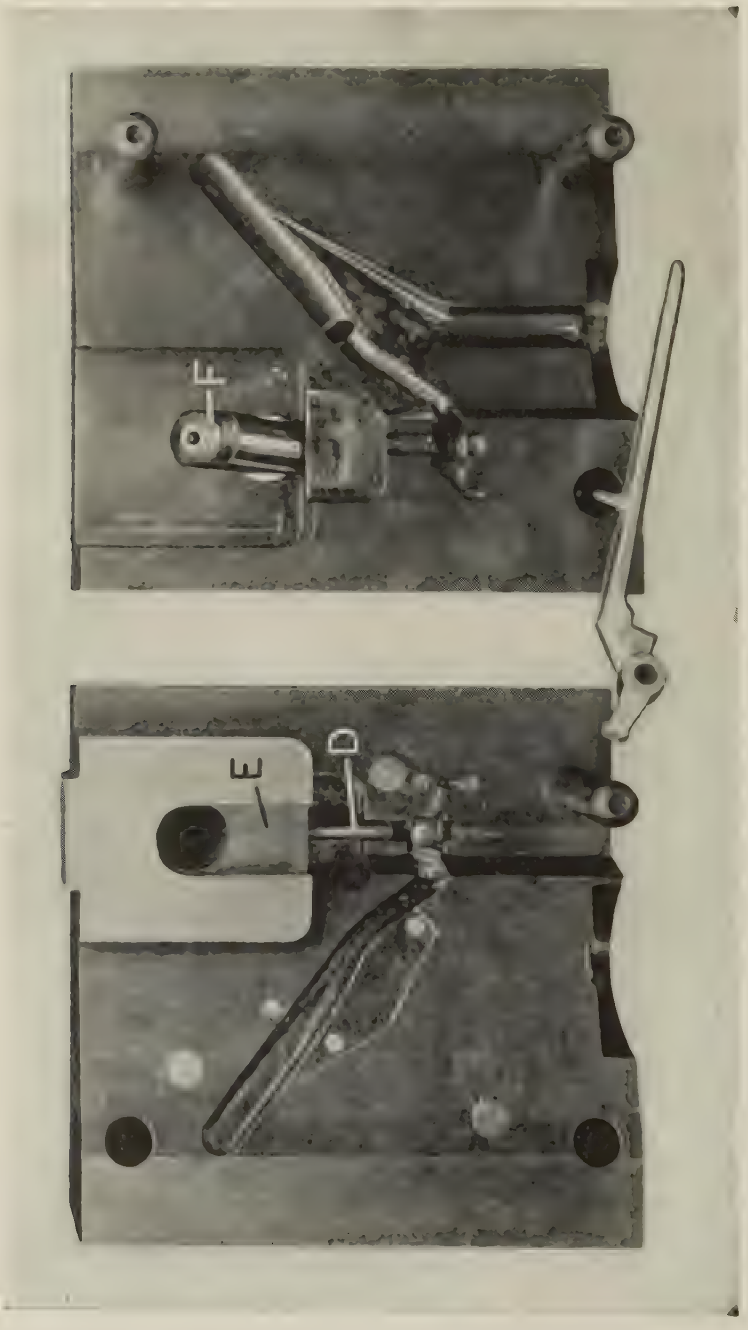


Fig. 13. Dies Made with a Parting Line of Unusual Irregularity, which was Necessitated by the Shape of the Part Produced

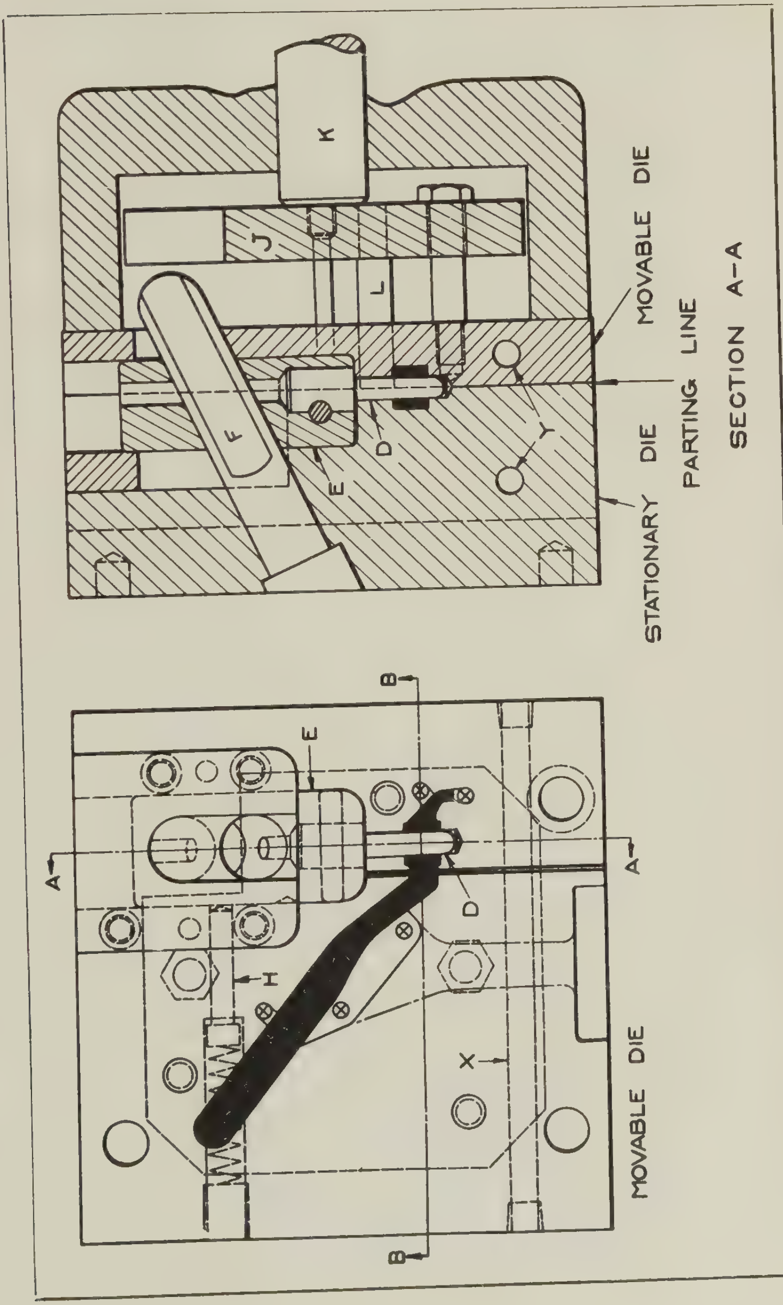


Fig. 14. Construction Drawing of the Dies Shown in Fig. 13. Note Irregularity of the Parting Line in the Lower View at the Left

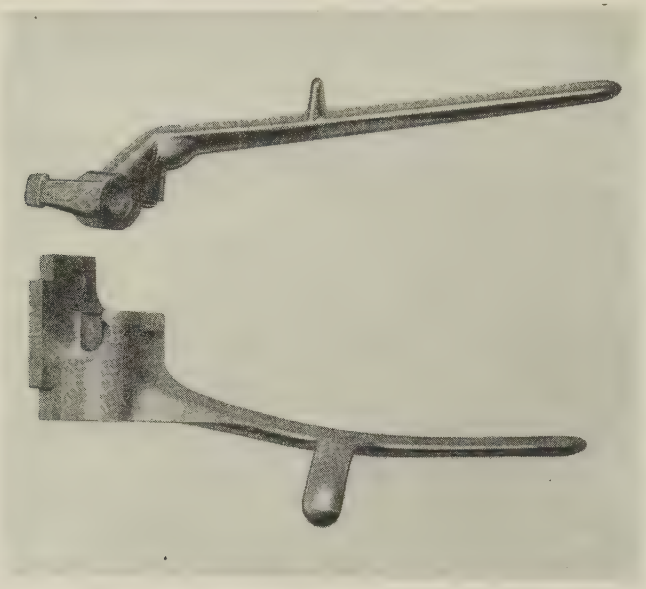


Fig. 15. Aluminum Hair-clipper Parts Cast in the Dies Shown in Figs. 13, 14, 16 and 17

pins are marked by cross-lines. Plate *J* is returned to the illustrated position by two pins *L* coming in contact with the face of the stationary die when the movable die is brought into the closed position.

Steel Insert in Casting.—A small steel axle, 1/4 inch in diameter by 7/8 inch long, is cast in one end of the lower clipper handle seen in Fig. 15. This axle is indicated by letter *X* in two views of Fig. 17, which show details of the dies that produce this handle. A photograph of the dies is reproduced in Fig. 16, the stationary die being shown at the left and the movable die at the right.

As this clipper handle is also an aluminum casting, the dies become too hot to permit the steel axle to be placed in the dies by hand. Hence, the movable die was made with a removable block *E*, which is taken out of the die after each operation and loaded with a new insert.

Block *E* is automatically moved sidewise a distance of

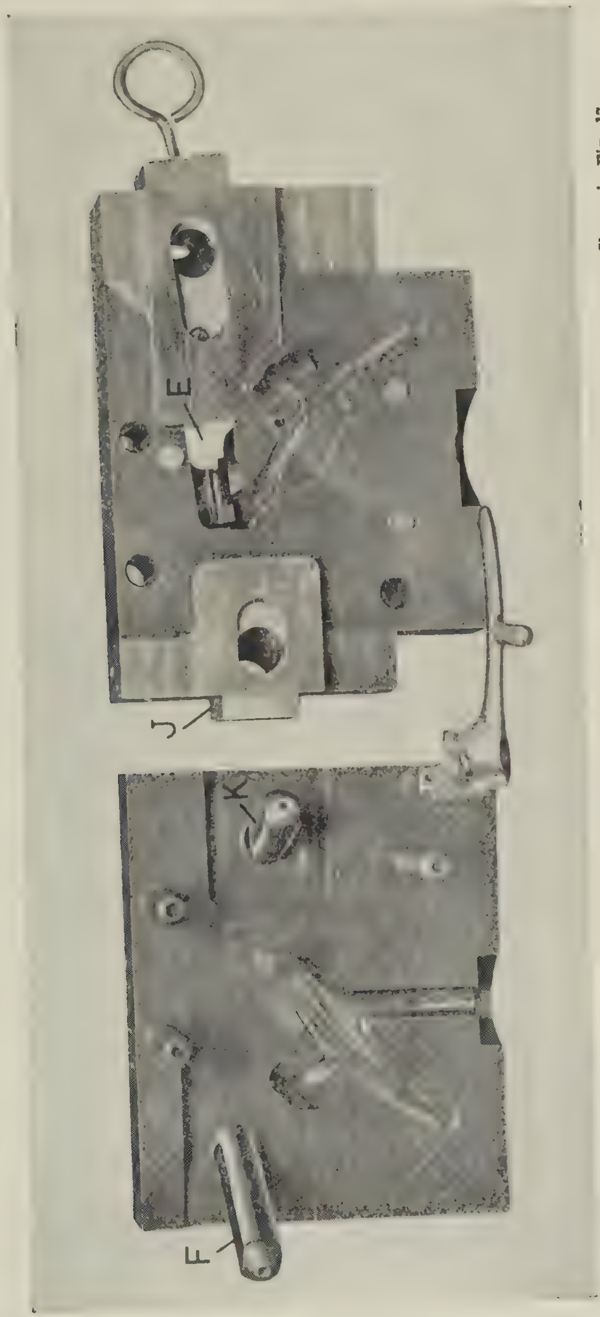


Fig. 16. Dies for Producing Hair-clipper Handle Shown at Bottom of Fig. 15. The Details of the Dies are Shown in Fig. 17

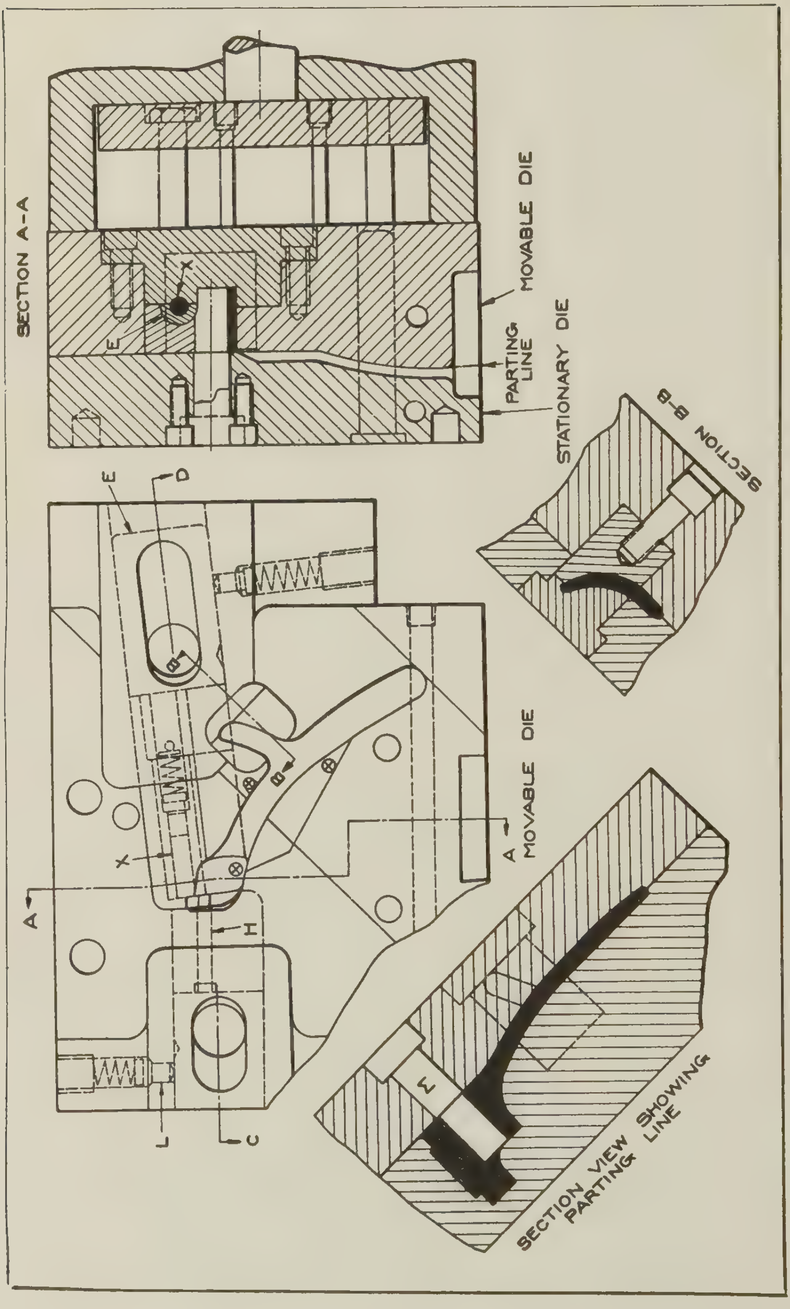


Fig. 17. Die-casting Die Made with a Removable Block to Facilitate the Casting of Small Steel Inserts in Aluminum Pieces

about 5/8 inch as it slides along pin *F* on the stationary die when the movable die is withdrawn. Then block *E* is removed completely from the die by the operator pulling on a handle attached to its outer end, as seen in Fig. 16. The insert is placed in a small hole in the left-hand end of block *E*, as shown in Fig. 17. A spring plunger backs up the insert, holding it against a surface of the cavity in the stationary die. Block *E* is located for casting by pin *F* when the dies are closed.

How the Core is Withdrawn.—Core *H* (Fig. 17) must also be withdrawn from the die cavity at the end of an operation to permit ejection of the casting. This is accomplished by mounting the core in a slide *J* (Fig. 16) which is moved sidewise when the movable die is opened, slide *J* being actuated by pin *K* on the stationary die. Spring detent *L* (Fig. 17) prevents slide *J* from being withdrawn completely from the die after it leaves pin *K*. It will be obvious that core *M* is fixed in the stationary die.

The method of ejecting the casting automatically from the movable die when it is withdrawn from the stationary member is the same as with the preceding dies.

By studying the illustrations, it will be observed that this set of dies is made up of an unusual number of pieces. This sectional method of constructing the dies greatly reduced the problems of the tool-room. Also, as the die pieces become worn, they can be replaced at minimum cost.

Die-Casting Thin Sections

Among the striking advances made during recent years in the art of die-casting, one of the most important is the ability to produce parts with extremely thin sections. The illustration Fig. 1 shows a small elbow casting, of which the wall thickness varies from 0.015 to 0.0175 inch—approximately only 1/64 of an inch.

This example also emphasizes the practicability of die-casting threads sufficiently accurate that no finishing operation is required except for removing the slight flash at the parting line in a trimming die. This thread is the American Standard or United States Form and twenty-four threads per inch are cast on the part shown. The pitch diameter is slightly under-size as a free fit is permissible with the part into which the thread is screwed.

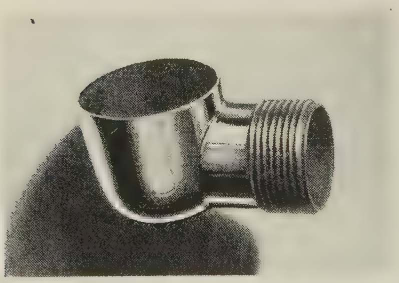


Fig. 1. The Wall Thickness of This Die-cast Elbow is only 0.015 to 0.0175 inch

This part is cast from zinc by the Schultz Die-Casting Co., Toledo, Ohio, at a pressure of 1600 pounds per square inch, which is the standard pressure employed by the concern for small or large die-castings and for thin or heavy sections. The elbow casting measures approximately 1 1/2 inches in over-all length. It has a 7/8-inch hole in one end and approximately a 9/16-inch hole in the other end. After being trimmed, this part is chromium plated.

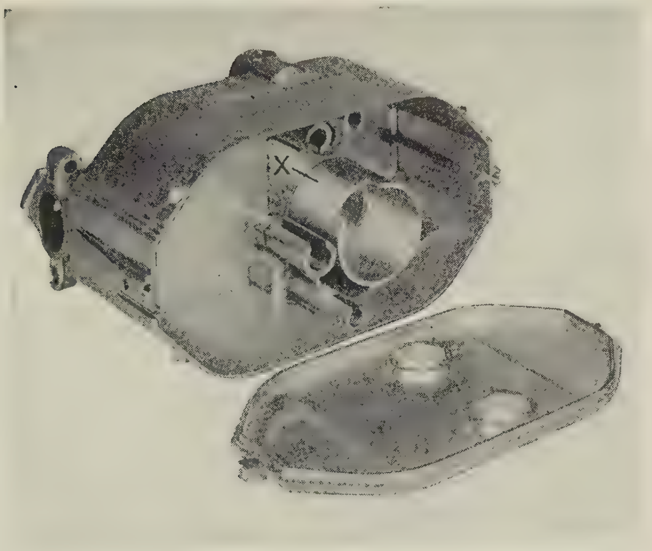


Fig. 2. Extensive Sections Only 1/16 Inch in Thickness are a Feature of This Die-casting

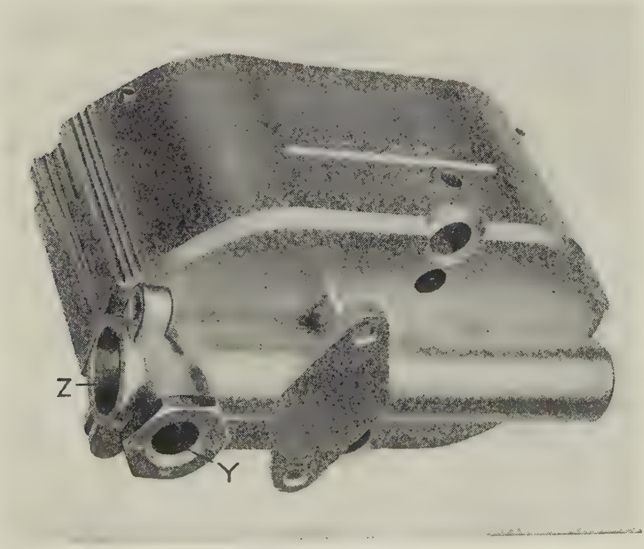


Fig. 3. The Bottom of the Oil-burner Float-valve has a Tubular Section with a Long Cored Hole

Die-Casting an Oil-Burner Float-Valve.—In cases where both thin and thick sections are required in the same casting, the designer must carefully study the flow of the metal in the die, and by water-cooling or the application of heat, provide for a uniform flow to all parts of the die-cavity.

The oil-burner float-valve illustrated in Figs. 2 and 3 has an outer wall only 1/16 inch thick, although the overall length of the part is approximately 5 5/8 inches and the inside height of the wall is 2 1/2 inches. This part also contains a cylindrical well *X*, which has a wall thickness of 1/16 inch. Integrally cast with the thicker bottom of the part is a long tubular section that is closed at one end. The hole *Z* in the tubular section is cored to a diameter of 13/16 inch. One of the special mechanical features of the dies used in casting this float-valve is the means employed for removing the long tube core at the end of the operation.

Features of Dies Used in Casting Oil-Burner Float-Valves.—The dies used in producing the oil-burner float-valve are illustrated in Fig. 4, the movable die being shown at the left with the various sliding members in the closed or casting position, and the stationary die being shown at the right. Fig. 5 shows the same dies, but in this illustration the movable die is shown with its sliding members in the open position for ejecting a die-casting. It will be apparent from these illustrations and from the construction drawing, Fig. 7, that the parting line for the casting runs around the top edge and also through its vertical center line, as shown in the plan view, Fig. 6. The entire piece is cast in the movable die member, the stationary member serving merely to close the die and to hold the cores for producing the various holes and openings.

Four holes are produced partially by cores in the stationary die and partially by cores in the movable die, the cores of the stationary member being piloted in holes in the movable-die cores. These cores are seen at *A* and *B*,

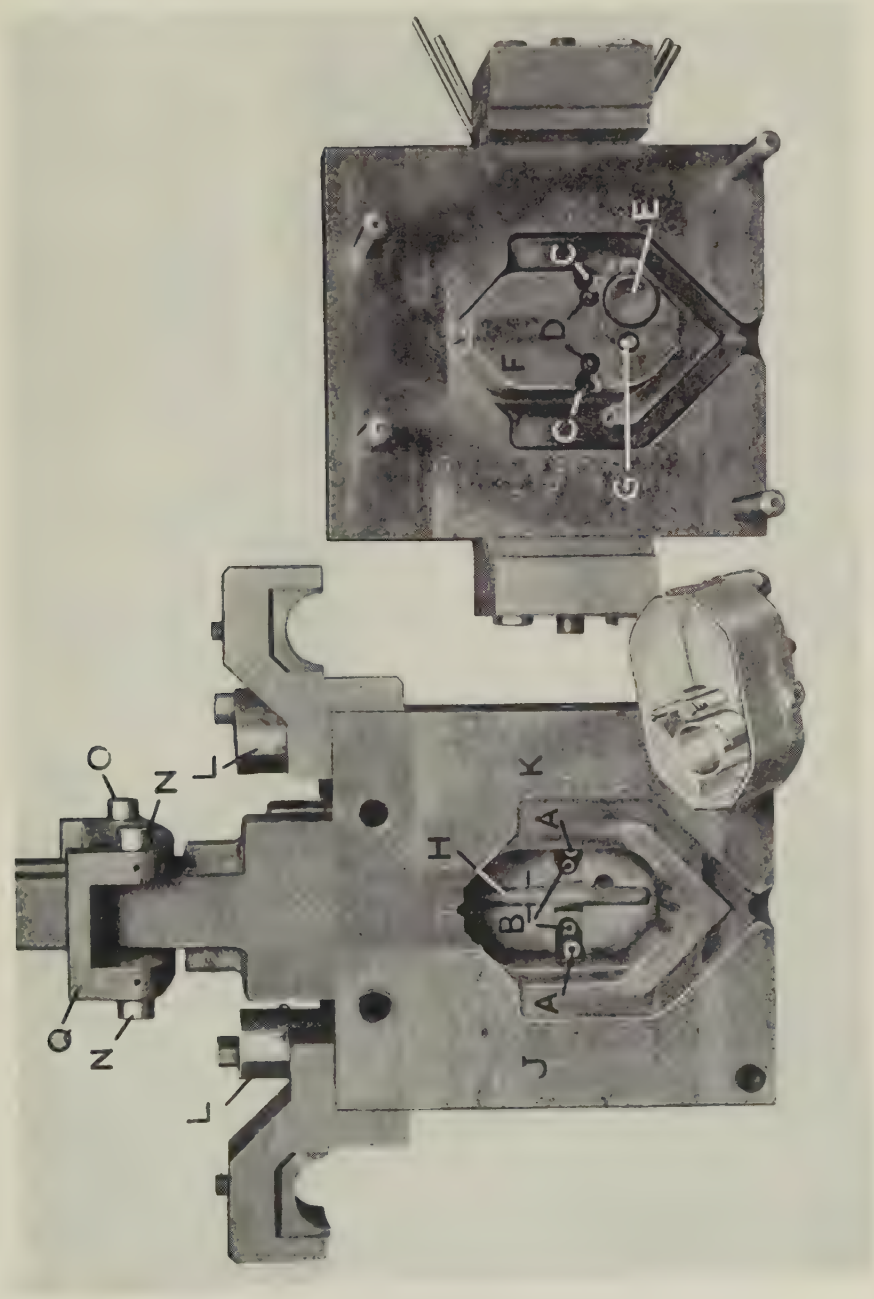


Fig. 4. Dies Used in Producing the Oil-burner Float-valve. The Movable Die at the Left is Shown with its Two Slides and a Moving Core in the Closed or Casting Position

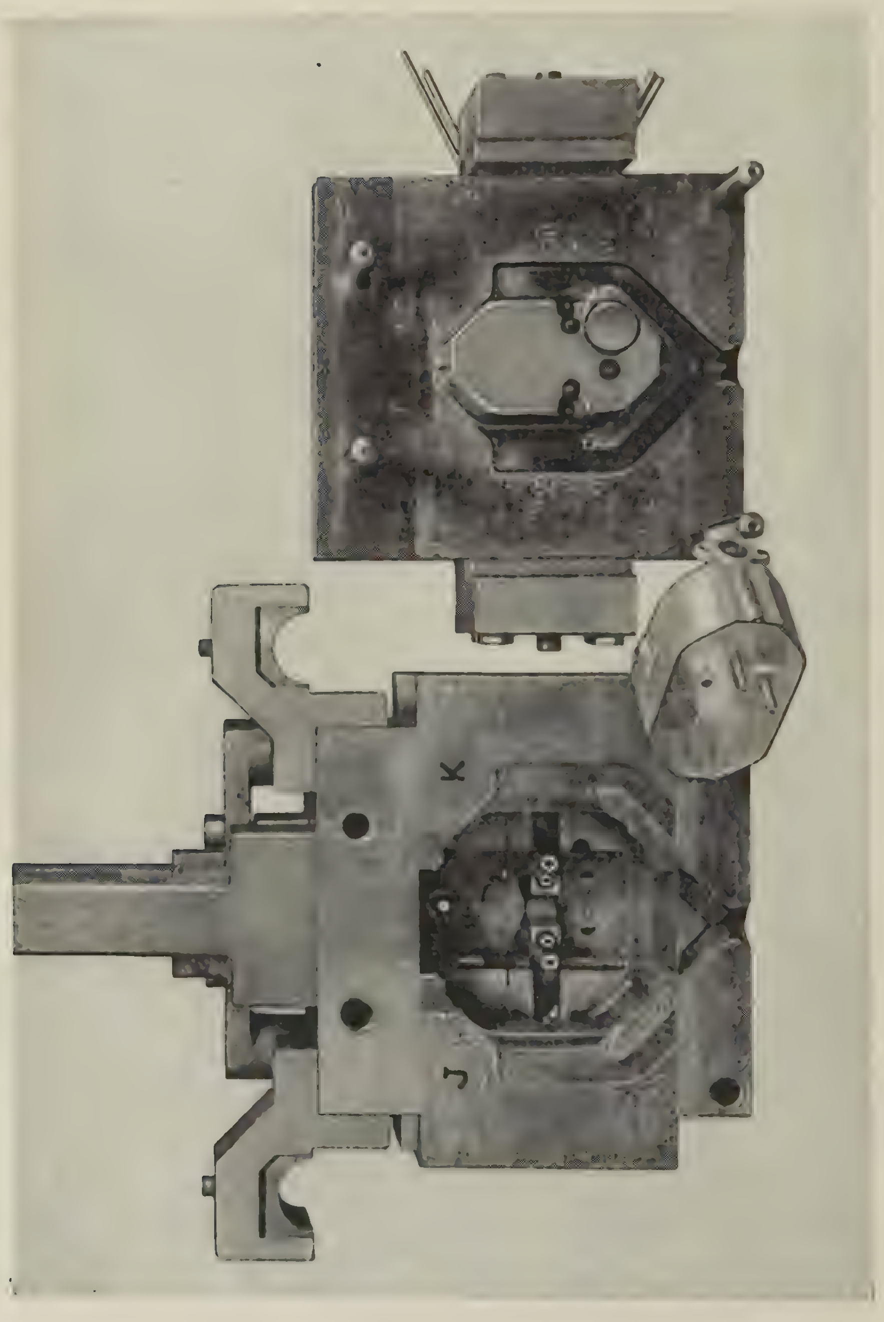


Fig. 5. Another View of the Dies Shown in Fig. 4, with the Various Sliding Members of the Movable Die in the Open Position for Ejecting a Casting

Fig. 4, on the movable die and at *C* and *D* on the stationary die. The construction of these piloted cores is shown in the upper right-hand view of Fig. 8. On the stationary member in Fig. 4 may be seen the top of the deep narrow circular cavity that is formed by cores *E* and *F* to produce well *X*, Fig. 2. At *G* in the upper left-hand view of Fig. 8 is shown a core that must be seated closely and slightly off center on core *H*, which produces the long hole *Z*, Fig. 3.

Gating of the Dies for Oil-Burner Float-Valves.— Gating is an important factor in the design of die-casting dies. From a study of Figs. 4 and 5, it will be seen that generous runners in both the movable and stationary members of the die carry the molten metal to the two sides of the cavity. These runners are 3/4 inch wide and are about 5/16 inch deep in each die half up as far as the lower edge of the movable-die slides. From here on there is a runner in the stationary die only to the point where the metal enters the die-cavity. Then runners are provided in the slides to a depth of 0.045 inch. At the points where the metal is forced into the die-cavity, however, the total depth of the opening on each side is only 0.045 inch, but the opening is approximately 4 inches long.

Operation of Dies.— In the operation of these dies, the regular equipment of the die-casting machine (Madison-Kipp) carries the movable member away from the stationary member. The two slides *J* and *K* of the movable member and core *H* are operated simultaneously. The two slides are moved 2 1/2 inches apart as the rollers on the end of crank-arms *L* (see Fig. 6) move along a cam path in the faces of horizontal "combination bars" *M* at the top of the machine. The crank-arms are mounted at the top of pinion shafts *S*, which engage racks fastened on the back of slides *J* and *K*. Thus the slides are operated by the action of crank-arms *L*. These arms swing 95 degrees into the position

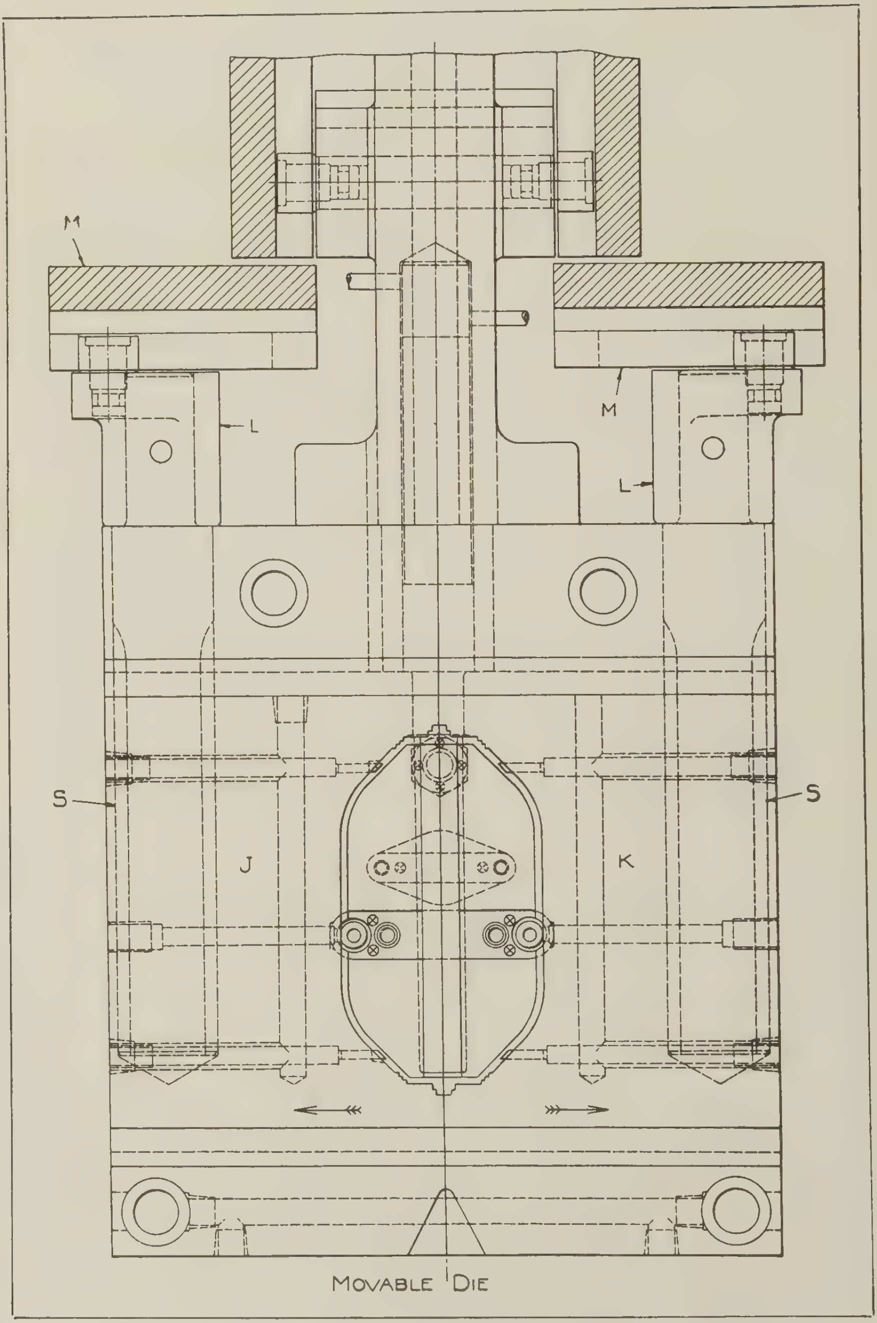


Fig. 6. Plan of Dies Shown in Figs. 4 and 5

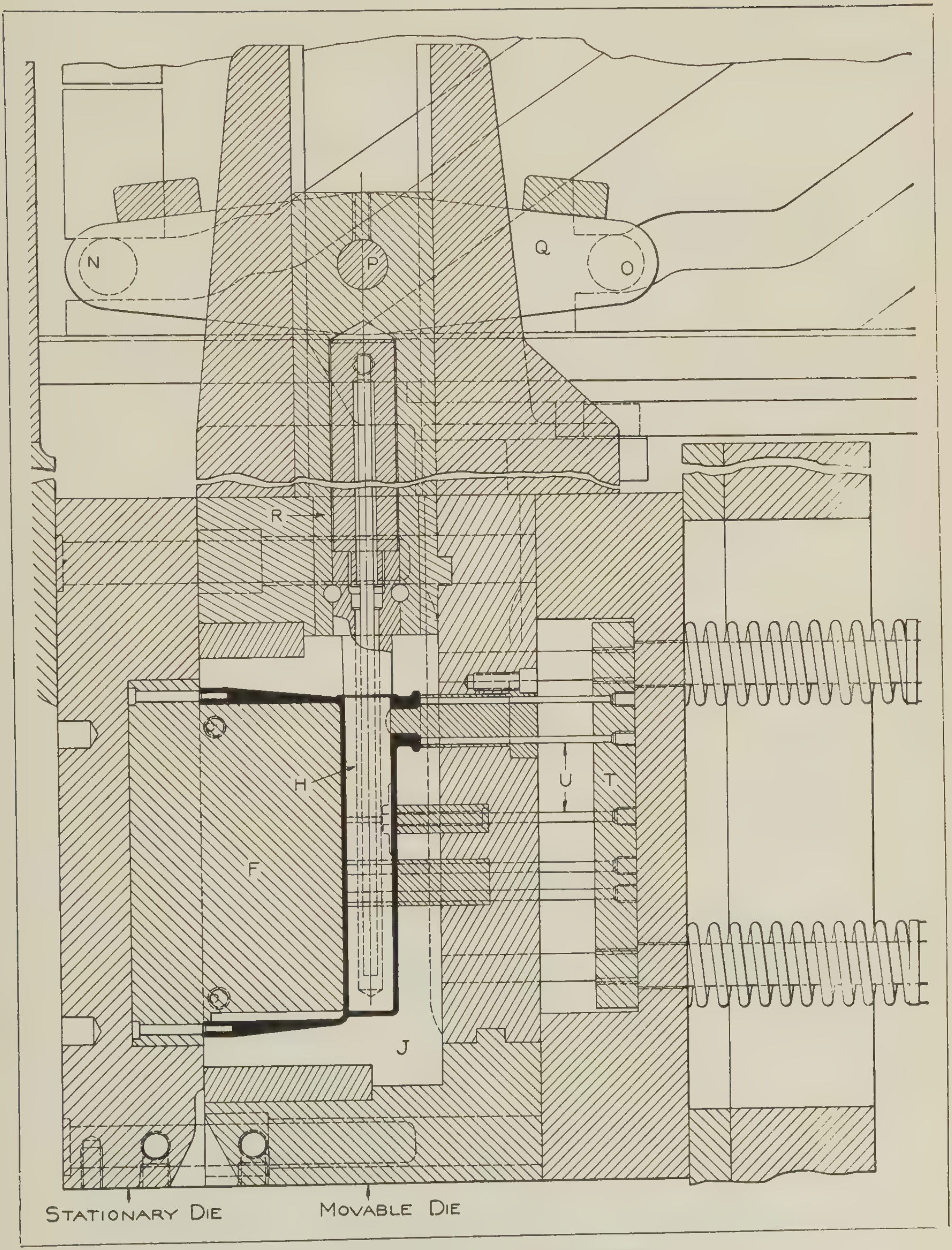


Fig. 7. Sectional View of Dies Shown in Figs. 4 and 5

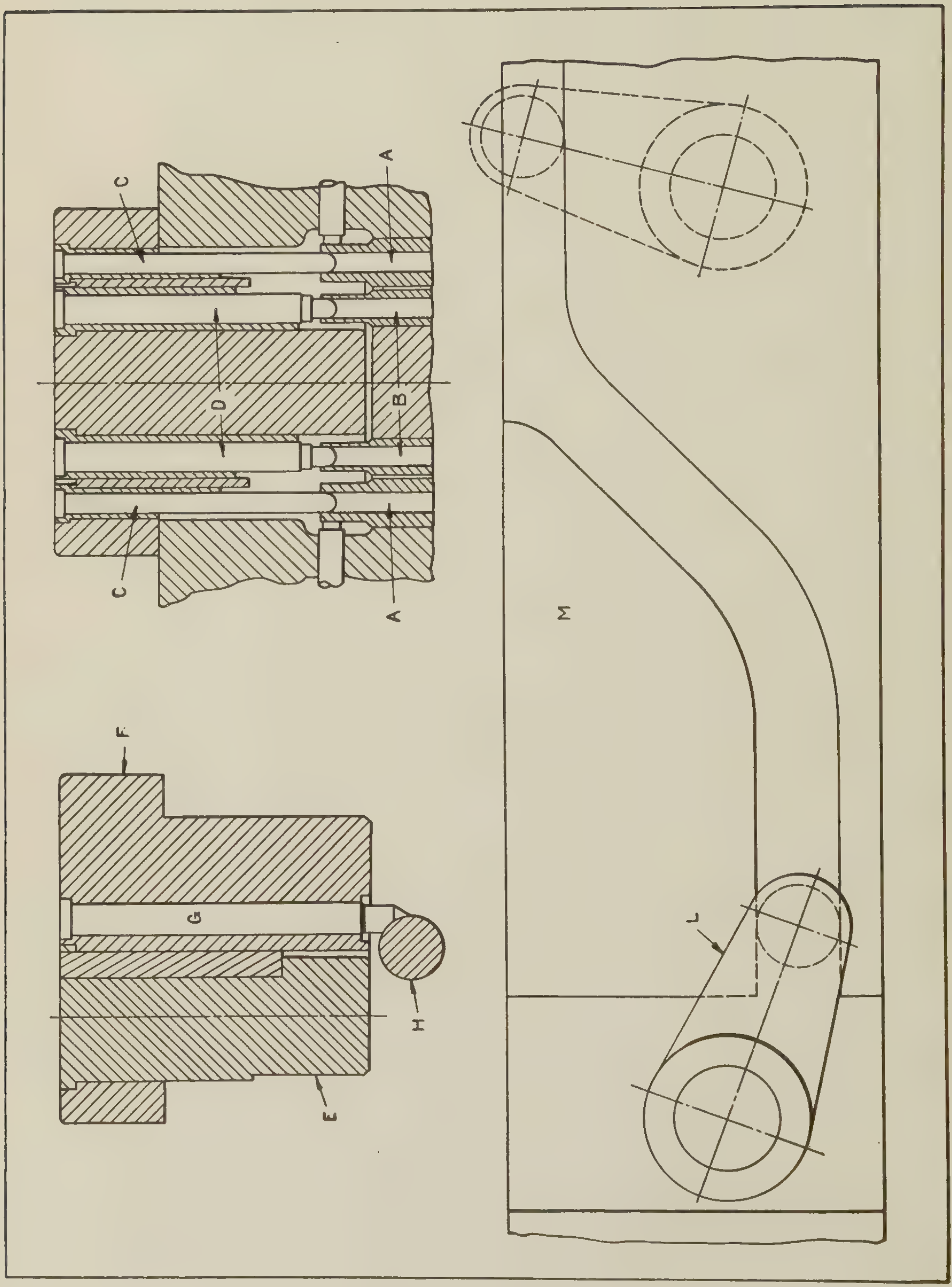


Fig. 8. Details of Cores in Dies Shown in Figs. 6 and 7 and Diagram of Cam that Actuates Crank-arms L

shown dotted at the right-hand end of the diagram at the bottom of Fig. 8.

At the same time, core *H* is broken loose from the casting in two quick jerks and is then withdrawn at a uniform rate from the casting. These movements are actuated by rollers *N* and *O* on a link *Q* that is pivoted on a pin *P*, Fig. 7, held in a slotted arm attached to the top of the movable die. Rollers *N* and *O* move along cam paths in the vertical faces of combination bars at the top of the machine. As the movable die starts to recede from the stationary die, roller *O* moves up a short incline in its cam path while roller *N* continues to move horizontally. This causes a long leverage action of link *Q* with roller *N* as the pivoting point. The result is that pin *P*, core-holder *R*, and core *H* are raised one-half the vertical movement of roller *O*, or about 5/32 inch. The action is a quick jerk that loosens core *H* from the casting.

As roller *O* then advances horizontally, roller *N* strikes a short incline, with the result that link *Q* pivots on the axis of roller *O*. This gives a second quick jerk that completely loosens core *H* from the casting. From this point, rollers *N* and *O* simultaneously move up inclines of the same angle, thus raising core *H* from the die. All other cores of these dies are fixed in either the movable or stationary members. However, several cores on slides *J* and *K* are withdrawn from the casting when these slides are opened sidewise.

Ejection of the Casting.—Ejection of the casting from the movable die is accomplished by means of ten long slender pins *U* mounted on plate *T*. This occurs when four rods attached to plate *T* strike stops on the machine as the withdrawal of the movable member ends. The ejection of the casting is facilitated because its large box-like exterior is slightly tapered. When the movable die again advances to the closed or casting position, springs surrounding the four rods attached to plate *T* pull the plate back and thus withdraw the ejecting-pins to the bottom surface of the die-cavity.

In this die, core *H* is water-cooled for practically its entire length. Water is also circulated through slides *J* and *K* and across the bottom of both the movable and stationary die members, so as to control the temperature of the dies in the vicinity of the sprue hole.

Rate of Production.—Die-casting production depends upon the amount of metal to be cast in wall sections, the size of the casting and other factors. In the case of the oil-burner float-valve, about two pieces can be produced per minute. This part is cast from zinc, which has become especially popular for die-casting because of its comparatively low melting point (approximately 810 degrees F.) and because zinc alloys are now available that give tensile strengths as high as 50,000 pounds per square inch. When lightness is a factor, aluminum alloys are used, as they are about 140 per cent lighter than zinc, or else magnesium, which is one-third lighter than even aluminum.

Another Die-Casting with Walls Only 1/16 Inch Thick.—Fig. 9 shows a rather complex die employed for casting the aluminum housing shown at *A*, which has a number of compartments separated by unusually thin walls. This casting is approximately 8 1/2 inches long by 4 inches wide by 6 3/8 inches deep, and some of the walls are only 1/16 inch thick. Owing to the thin casting section at the gate, the hot metal for this comparatively large casting must be forced into the cavity through an aperture only 3/16 inch wide by 4 inches long.

Originally, difficulty was experienced in forcing the metal to the extreme points of the die, with the result that blowholes and too thin walls were obtained. Grooves were then cut in one die member to lead the metal to the distant points. These grooves produce corresponding ribs on the part, which not only reinforce it, but also improve its ap-

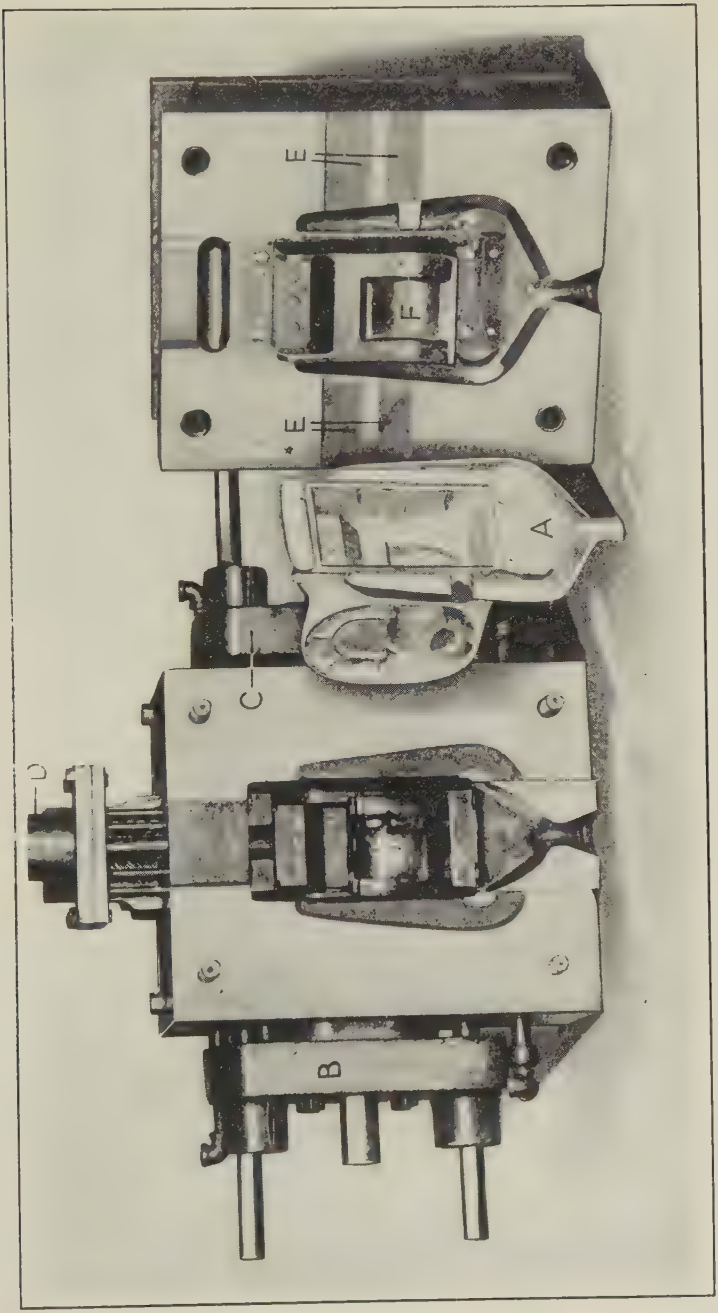


Fig. 9. Complicated Die for a Comparatively Large Part Having Several Compartments with Unusually Thin Walls between them

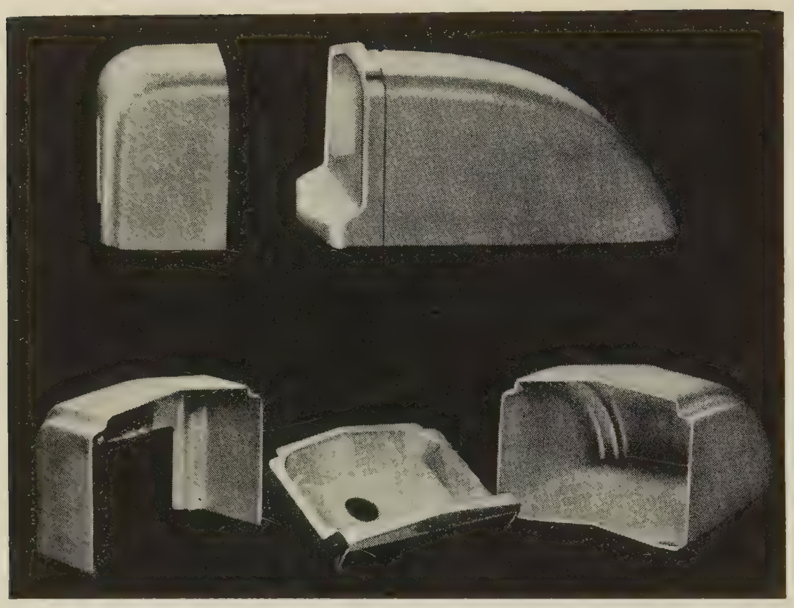


Fig. 10. Thin Walls Permit Die-cast Water-cooler Parts to be of Minimum Weight

pearance. The die is designed with the parting line located along one edge of the casting, from which fins can easily be removed.

Cores are pulled from this die on both sides and from the top, these cores being attached to heads *B*, *C*, and *D*, respectively, which are mounted on the stationary member. The casting is made to adhere to the moving member when the die opens. Air vents are seen on this member at *E*. Block *F* on the moving member protrudes a considerable distance into the cavity of the other die half. Ejector-pins may be seen at various points on the moving member. Twenty-five holes are cored in this casting, and by employing the die-casting process for making this part, the machining of an oval opening is obviated, as well as the milling of a semicircular frame recess.

Brass Die-Casting Process

The brass die-casting industry has been developed to a point where copper-base castings are produced in large quantities for regular commercial use. In one plant—the Titan Metal Mfg. Co., Bellefonte, Pa.—approximately 175,000 brass die-castings are produced per month and the total weight of the annual production is over 1,000,000 pounds. Cold chamber machines using plastic and liquid metal are capable of producing brass die-castings having a maximum projected area of 70 square inches. Depending on the shape of the piece considered, the practical maximum weight limit is 5 pounds.

Alloys available for brass die-casting include, besides the usual yellow brasses, silicon brass, several Tinicosil alloys, and other patented alloys. The copper-base alloys have the highest tensile strength of any of the die-cast alloys and are therefore useful for the production of parts that require structural strength as well as hardness. The successful die-casting of brass has been made possible by the development of alloy steels that have a satisfactory life when used for dies subjected to high temperatures and by the development of suitable die-casting machines.

Advantages of Brass Die-Castings.—The principal advantages of brass die-castings over sand castings are better appearance; greater strength; more uniform cross-sections, due to less likelihood of blow-holes; and more economical production when sufficiently large quantities are required. In addition, die-castings generally do not require so much machine work as sand castings, and when they do, the cutting tools last much longer because of the absence of sand in the castings. Die-castings can be produced to sharper

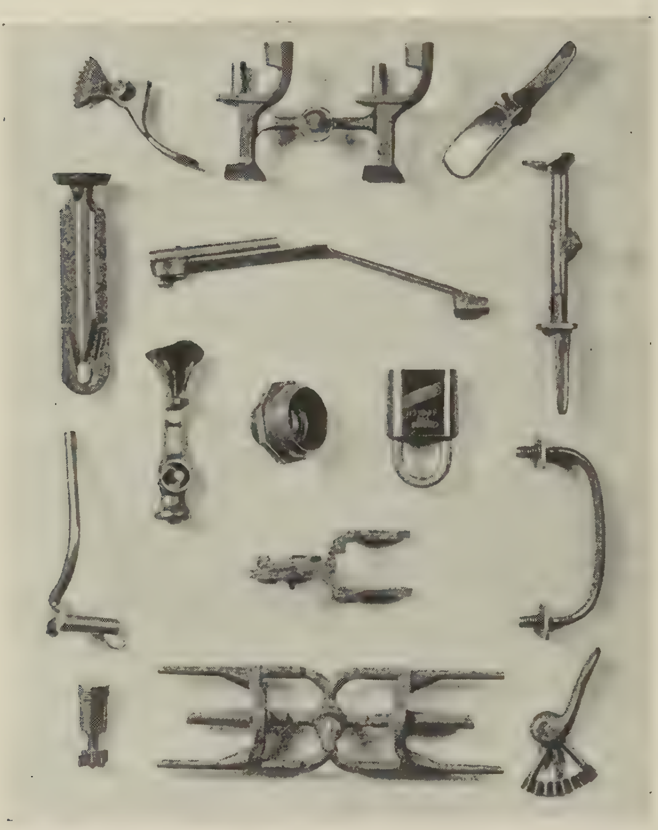


Fig. 1. Brass Die-casting Can be Advantageously Employed for the Production of a Wide Variety of Parts. Some of the Examples Here Shown Have Cast Threads, and Others Cast Gear Teeth

outlines and closer tolerances than sand castings and to sections as thin as 0.030 inch. Important dimensions can be held to an accuracy within + or — 0.003 inch and even closer.

Defective scrap in sand casting generally runs between 10 and 15 per cent, whereas in die-casting, the defective scrap loss ranges between 7 and 10 per cent, and it can be readily reclaimed by merely remelting.

Brass Die-Castings Versus Brass Forgings.—Brass die-castings can generally be produced cheaper from the virgin

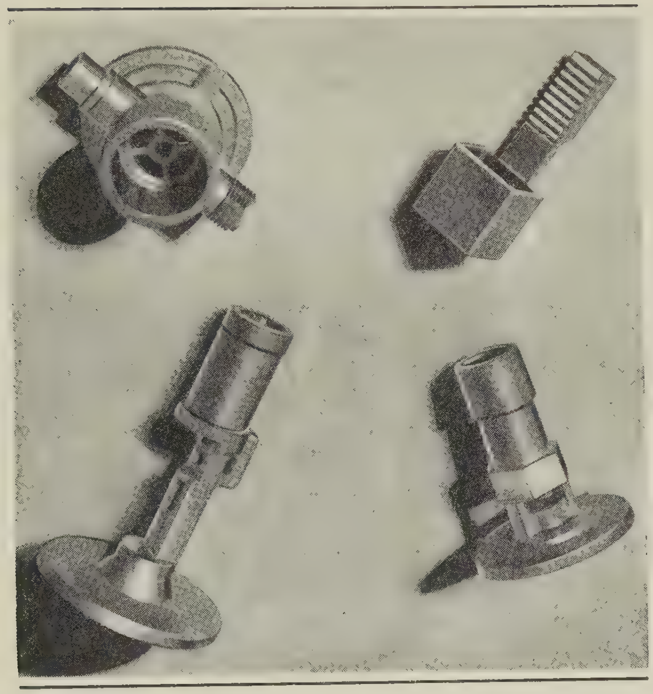


Fig. 2. Additional Examples of Brass Die-casting

metal than brass forgings. With die-casting, only a melting furnace, a die-casting machine, dies, and equipment for producing the required pressure are needed. On the other hand, to produce brass forgings, equipment is required for casting ingots, sawing the ingots into billets, heating the billets, extruding rods, sawing the rods into slugs, heating the slugs, and forging the slugs into the desired parts.

Another great advantage of brass die-castings in comparison with forgings is that holes can be cored with comparative ease. Die-castings can be produced to knife-edges and with sharp corners.

Brass die-castings, however, cannot be produced with the same density as forgings, and the die-cast metal is porous to some extent. Hence, die-castings should not be used when water, gas, or air is to be conducted through them under extra high pressures. The defective scrap loss in forging practice is much less than in brass die-casting, being only from 3 to 5 per cent.

Applications of Brass Die-Castings.—Brass die-castings are used primarily where high strength or corrosion resistance is of especial importance. Aluminum-bronze die-castings have a tensile strength greater than that of regular structural steel.

Brass die-castings are excellent for pipe fittings and for most classes of liquid-handling and gas-handling equipment; for marine fittings; for hardware; for many machine parts; and for a large variety of other applications. They are free from intergranular corrosion and are not subject to the season-cracking which sometimes occurs in stamped and other wrought parts of similar alloys. A general idea of the variety of parts which can be cast from brass may be obtained from Figs. 1 and 2, although these illustrations show only a few of the numerous parts now being cast successfully from copper-base alloys.

Casting the Metal while in a Semi-Liquid or Plastic Condition.—In the development of brass die-casting, the principal difficulty to be overcome was that of the short die life, due to the comparatively high melting point of the metal being cast. The alloys mainly cast by the Titan Metal Mfg. Co. have melting points between 1650 and 1675 degrees F. At such high temperatures, the best of alloy die steels are not likely to last long, unless provisions are made to keep the dies from becoming too hot.

The Polak die-casting machines used in this plant are designed on the principle of casting the metal while it is in a semi-liquid or plastic condition rather than in the completely molten state. This allows the metal to be cast at a temperature several hundred degrees lower than when it is shot into the dies in liquid form. In addition, cold water is

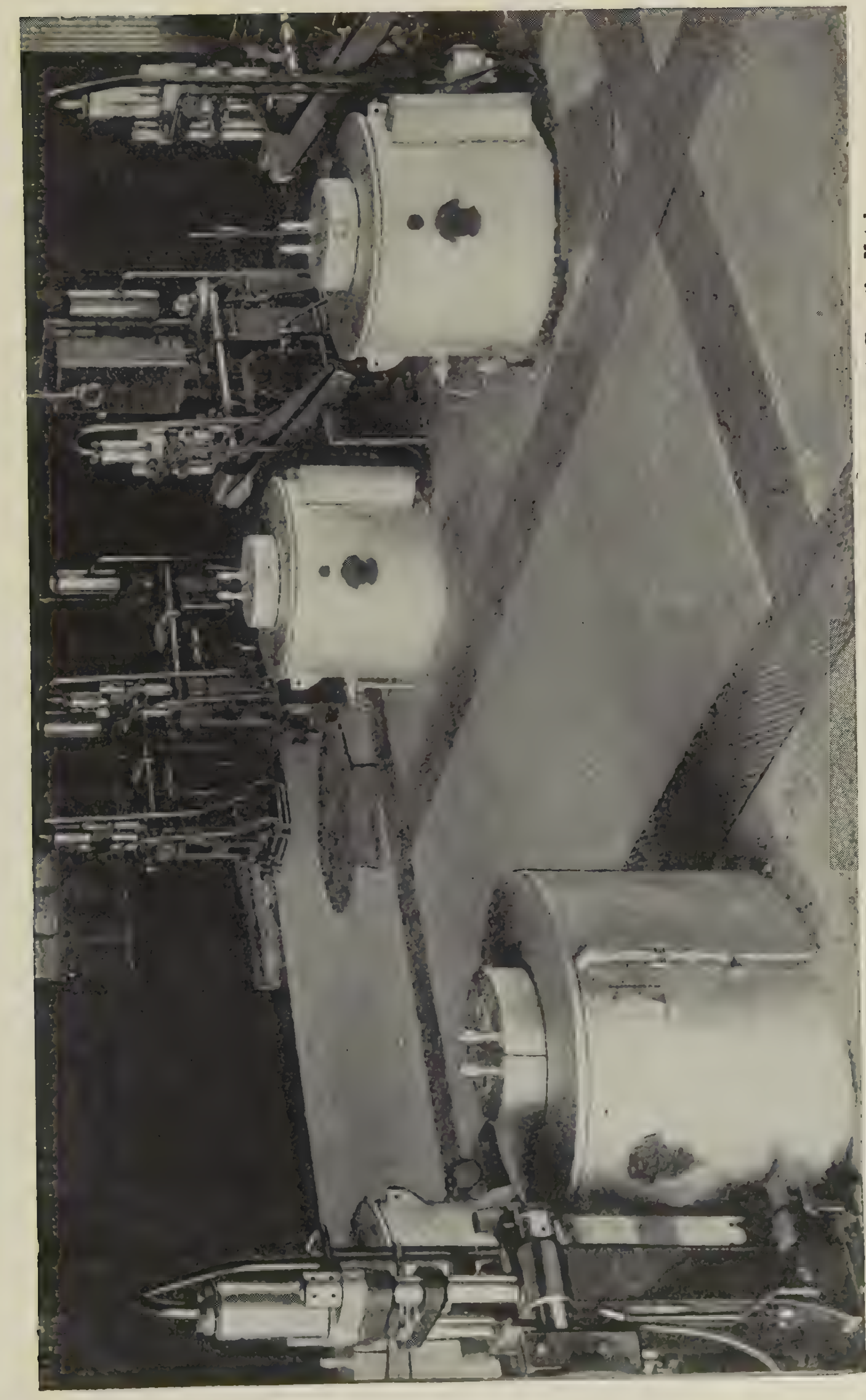


Fig. 8. Battery of Polak Brass Die-casting Machines. Note the Electric Furnaces which Keep the Metal in a Semi-liquid or Plastic Condition

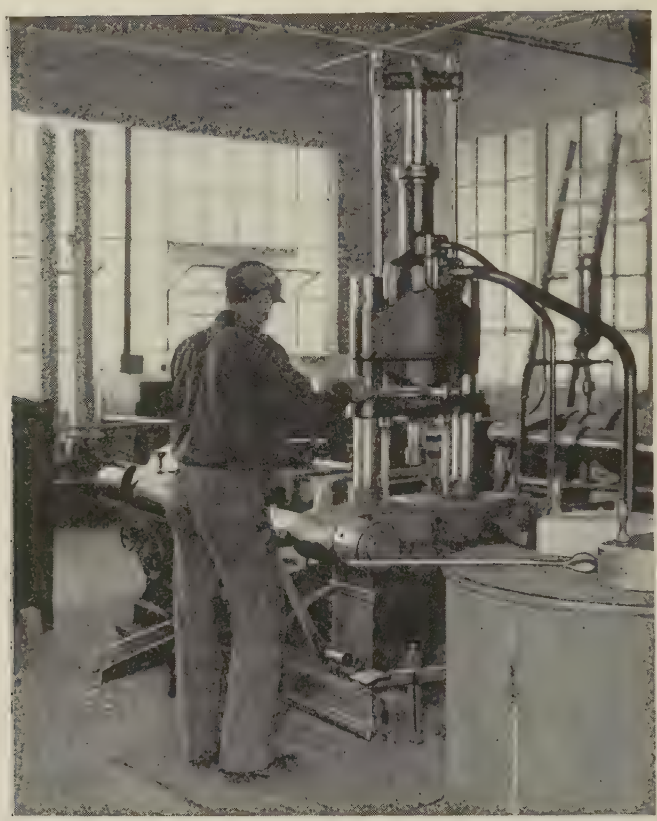


Fig. 4. This Machine Exerts a Pressure of 9800 Pounds per Square Inch in Forcing Plastic Brass into Dies for the Production of Die-castings

constantly circulated through plates in back of the die faces to prevent them from becoming heated beyond 600 degrees F. Cold water could not be used directly in the dies for this purpose, as it would cause them to crack.

Electric Furnaces Adjacent to the Machines Hold the Metal at the Proper Temperature.—One of the most important factors in successful brass die-casting is to maintain the metal in the proper plastic condition. Electric furnaces located adjacent to each of the die-casting machines, as may be seen in Fig. 3, serve this purpose. These furnaces are charged from time to time with molten metal that is brought from melting furnaces in a nearby department. When a new charge is hotter than the normal temperature, slugs obtained in the production of previous castings are thrown into the charge to cause a reduction in its temperature. All scrap metal is carefully analyzed at least once a day. Pyrometers and automatic thermostatic controls insure that the electric furnaces are held within the proper temperature range throughout the day. The furnaces are not permitted to vary more than 10 degrees from the mean temperature specified for any alloy.

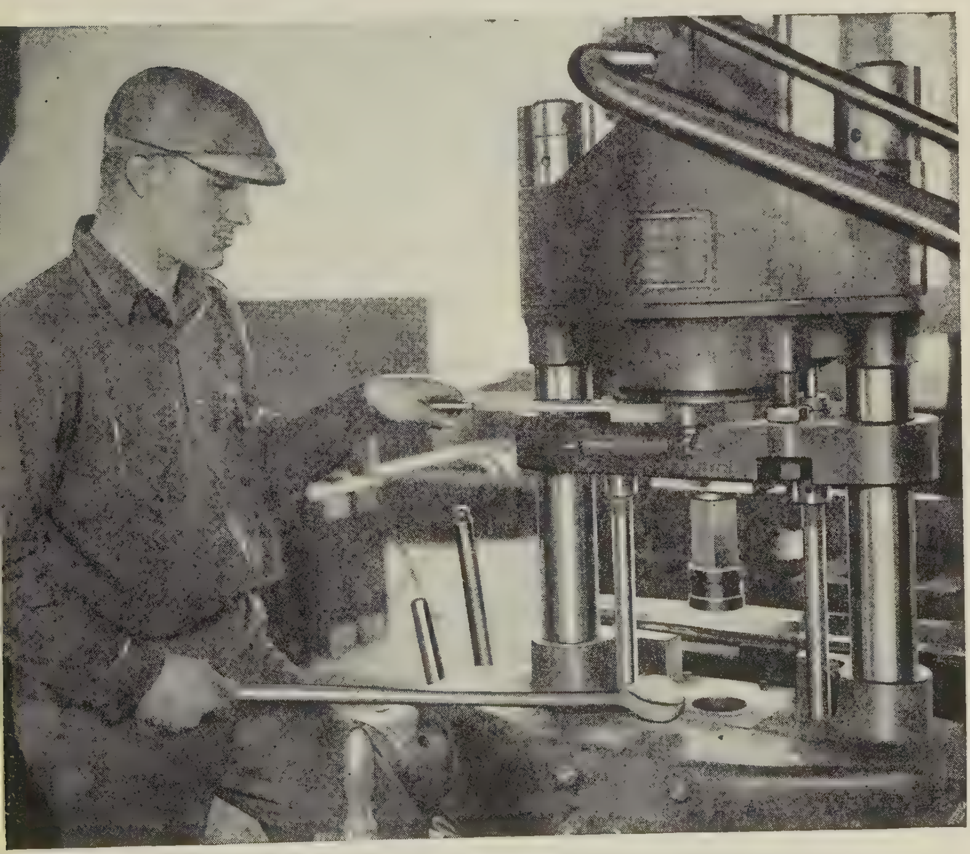


Fig. 5. The Plastic Metal is Ladled from a Melting Pot to the Compression Chamber of the Machine

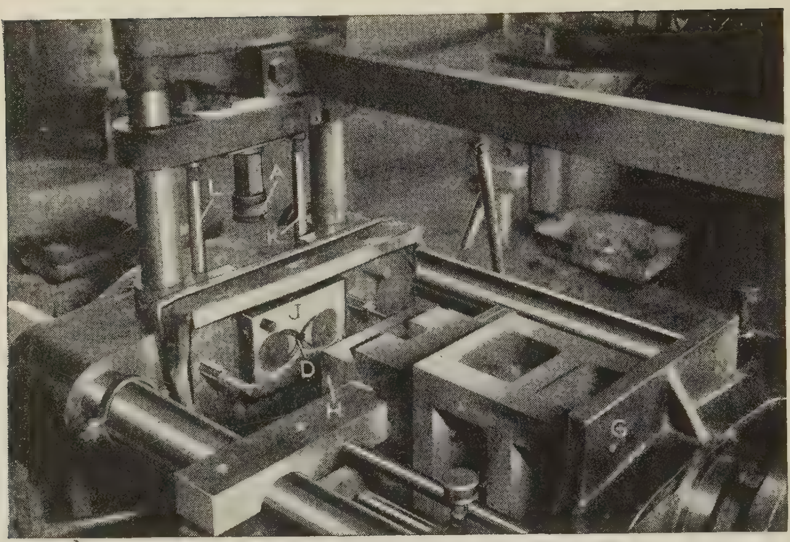


Fig. 6. The Dies in this Machine Simultaneously Produce Two Brass Disks 4 Inches in Diameter and Only 0.063 Inch Thick

General Method of Operating Polak Machine.— Figs. 4 and 5 show views of the largest of the Polak machines, which develops a pressure of 9800 pounds per square inch on the 3-inch ram. Adjacent to this machine is an electric furnace which is maintained at a temperature as high as required to keep the metal at the desired plasticity. The metal is ladled from the melting pot to the compression chamber of the machine, as shown in Fig. 5. Ladles of different sizes are used, slightly more metal being poured into the compression chamber than is required for each casting operation. The surplus metal is ejected in the form of a slug which is remelted and used again.

Prior to emptying a charge of plastic metal into the machine, the operator moves a long lever at his left which actuates a valve that closes the movable die against the stationary member and holds it in this position for the operation. The moving and clamping of the movable die are effected under a hydraulic pressure amounting to about 120 tons on the large machine.

How the Plastic Metal is Forced into the Die-Cavity.—After the dies have been closed and the plastic metal emptied into the compression chamber, the operator depresses a foot-pedal, which causes the hydraulically actuated ram *A*, Fig. 6, to descend into the compression chamber. The action of the ram is illustrated diagrammatically in Fig. 7. It will be seen that when the plastic metal *B* is emptied into the compression chamber, it drops on top of a spring-backed ejector plunger *C*. When the ram descends, it pushes both the charge of metal and ejector *C* downward until the opening in gate *D* is exposed. The plastic metal is then forced through this gate and into the die-cavities. When both the die-cavities and the gate have been solidly filled with metal, the ram *A* returns to its upper position.

Simultaneously with the upward movement of ram A, ejector *C* is pulled upward, as indicated in view *Y*. With this movement, ejector *C* shears off the sprue and discharges the surplus metal left in the chamber, which is now

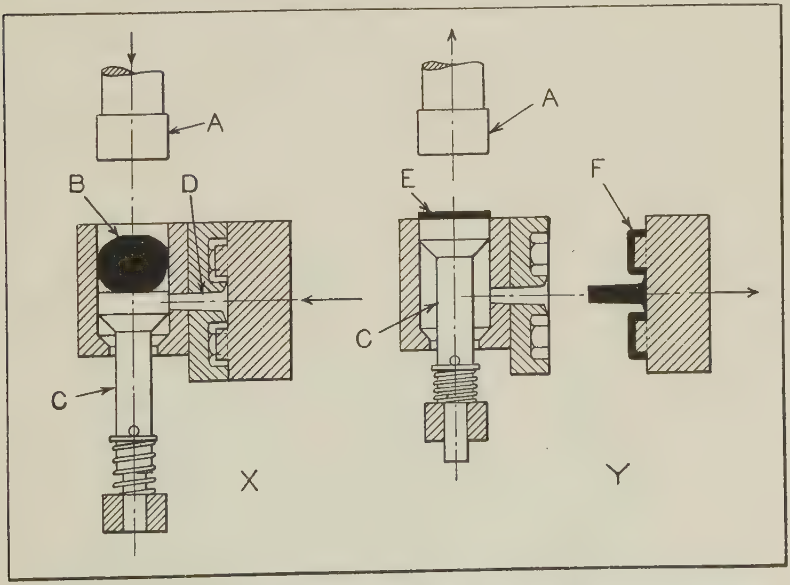


Fig. 7. Diagrams Illustrating the Action of Polak Machines in Pressing Die-castings from Copper-base Alloys in the Plastic State

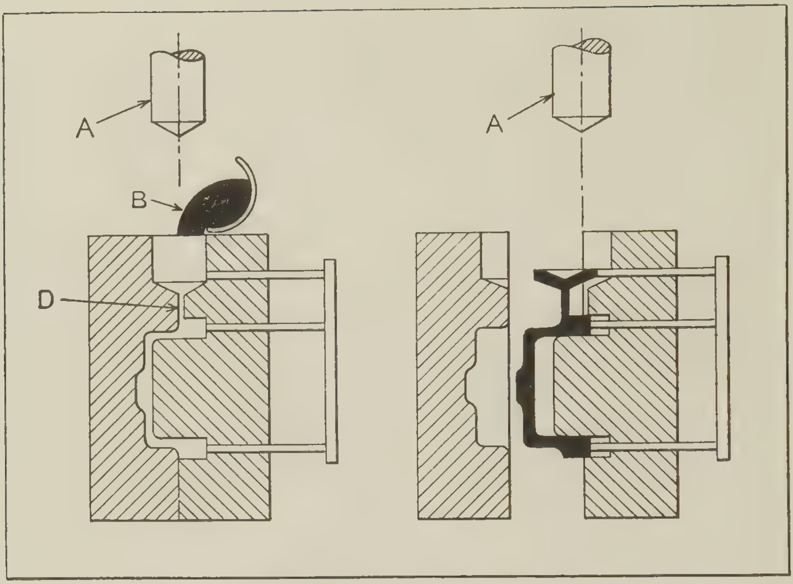


Fig. 8. Diagrams Showing Brass Die-casting Dies with the Compression Chamber in the Dies

in the form of a solidified disk, as indicated at *E*. This slug ranges from 1/8 to 3/16 inch in thickness. In view *Y*, the movable die is shown withdrawn from the stationary die and the finished die-casting *F* is indicated on the face of the movable die.

Compression Chamber Located in the Die.— Polak machines have been built with the compression chamber in the dies themselves, as indicated in Fig. 8, rather than in the frame of the machine. The left-hand diagram illustrates the pouring of a charge of plastic metal *B* into the compression chamber; then the metal is forced by ram *A* into the die-cavities through a vertical gate *D*. In the right-hand view of the illustration, the die-casting (indicated by solid lines) is being ejected from the stationary half of the die. In this method of casting, the surplus metal remains integral with the gate metal and must be trimmed off in a subsequent operation.

Operation of Movable Die, Vertical Ram, and the Casting Ejector.—The general construction of the various sizes of Polak die-casting machines is the same. Large-diameter bars extend from the right-hand to the left-hand end of the machine to tie the large cylinder at the left-hand end (which actuates the movable die) to the upright casting at the right-hand end which contains the compression chamber and supports the overhead hydraulic equipment that operates the vertical ram. Ram *G*, Fig. 6, to which the movable die is attached, as shown at *H*, slides on the large horizontal bars.

In this illustration, the face of the stationary die may be seen at *J*, the gate leading from the compression chamber being seen at *D*. When the movable die opens, the casting falls down into a chute that leads to the front of the machine while the operator brushes the slug of surplus metal into a chute at the right-hand end of the machine that leads to a container at the back. On some machines, a lever automatically sweeps across the top of the compression chamber to throw the slug into its chute.

The raising of the ejector in the compression chamber at the end of each operation is effected by means of the lever that the operator is seen grasping with his left hand in the illustration Fig. 5. When the vertical ram reaches the end of its downward stroke, this lever is pulled toward the machine by a coil spring, so that it latches under a collar attached to rod *K*, Fig. 6. Rods *K* and *L* are attached to a slide that carries ejector *C*, Fig. 7. Thus, when the vertical ram rises, rods *K* and *L* and the ejector are lifted with it to eject the slug of surplus metal, as already mentioned. When this has been accomplished, the operator pulls the lever forward, as shown in the illustration (see Fig. 5), thus releasing rod *K* and permitting the ejector to fall into position for receiving the next charge of molten metal. The 3-inch ram has a clearance of 0.004 inch in the compression chamber.

Hydraulic Pressure System for Operating the Die-Casting Machines.—Water is the medium employed to produce the hydraulic pressure for operating the die-casting machines. This pressure is developed at the Titan plant by a triplex pump, driven by a 30-horsepower motor. The pump has a capacity of 30 gallons of water per minute at a pressure of 1750 pounds per square inch. The pump is used in combination with air-loaded accumulator tanks. The hydraulic pump runs constantly when the plant is in operation, but an air compressor need only be run two hours a month to maintain the required air pressure in the accumulator tanks. These tanks are 15 feet high.

Each of the die-casting machines is equipped with prefill cylinders adjacent to the horizontal ram cylinders, thus greatly reducing the amount of water under pressure that must be admitted into the cylinders for closing and locking the movable dies. On some of the machines, the piston of the prefill cylinder also intensifies the pressure on the water that is admitted. With this arrangement, from 3 to 4 gallons of water under high pressure are saved at each operation of a machine. Each operation of the largest die-casting machine consumes only from 1 1/2 to 2 gallons of water under the high pressure. This machine has a capacity for casting parts with an area up to 25 square inches or a weight up to 11 pounds.

Casting Capacities of Different Machines and Rate of Casting.—The smallest machines in the plant are equipped with a 1 3/4-inch ram which applies a pressure of 4980 pounds per square inch on the metal being cast. This size machine will cast parts with an area up to 7 square inches and a weight up to about 10 1/2 ounces. It consumes 1/2 gallon of water under high pressure at each operation. The medium-sized machines are fitted with 2 1/4-inch rams which exert a pressure of 5500 pounds per square inch on the metal being cast. Pieces up to 13 square inches in area and up to 21 ounces in weight can be produced in these machines.

The largest die-casting machine can be operated at the average rate of 100 "shots" an hour, while the other machines can be operated at from 1700 to 1800 "shots" per eight-hour day. Maintenance costs up to the present time on the die-casting machines themselves have been negligible, as no repair parts have been required even on the smaller machines which have been in use for four years. The repacking of valves is the principal expense.

Brass die-castings have been produced with sections as thin as 0.030 inch, although this is really not practical commercially. The parts produced by the die seen in the machine in Fig. 6 are examples of quantity-production thin-section castings. These parts are disks 4 inches in diameter and only 0.063 inch thick.

The number of castings that can be made at one time depends upon their shape and size. In some cases, the casting must be produced singly, and in others as many as six can be produced at a time.

Alloys Used for Brass Die-Castings.—Experimentally, practically any copper-base alloy can be die-cast, but in actual practice, certain problems arise, such as the rapid deterioration of the steel dies when the temperatures are too high. It has been found feasible, for instance, to cast alloys having a copper content as high as 93 per cent which have a melting point of about 1820 degrees F.

Alloys used extensively by the Titan Metal Mfg. Co. in brass die-casting are a yellow brass and Tinicosil No. 10. The yellow brass contains about 62 per cent copper, 36.5 per cent zinc, 0.50 per cent tin, and 1.0 per cent lead. Tinicosil No. 10 contains 47 per cent copper, 39 per cent zinc, 1.5 per cent lead, 10.5 per cent nickel, 1 per cent manganese, and 1 per cent iron. The yellow brass has a tensile strength of 58,000 pounds per square inch, whereas Tinicosil No. 10

has a tensile strength of about 90,000 pounds per square inch.

Alloys such as zinc, aluminum, and lead have also been cast successfully in the Polak die-casting machines from the plastic state.

The Dies Used in Brass Die-Casting.—The dies for brass die-castings must be made of steels that will withstand to as great a degree as possible the high temperature of plastic brass. They must be heat-treated, and they must be dressed constantly while in use to remove the oxide which builds up in the die-cavities. The dies must be preheated at the beginning of each run.

How dies should be made for satisfactory brass die-casting and how they should be taken care of to insure a sufficiently long life for economy will now be considered.

To withstand the temperatures involved in the die-casting of copper-base alloys, it is necessary to make the dies from a steel of the semi-high-speed type. One of the steels that has been found most satisfactory by the Titan Metal Mfg. Co. for the making of die-casting dies has the following analysis: Tungsten, from 10 to 12 per cent; carbon, from 0.30 to 0.40 per cent; chromium, 1.75 per cent; and vanadium, 0.50 per cent. This steel is heat-treated to develop its heat-resisting properties.

The Life of Brass Die-Casting Dies.—The life of dies used for casting brass depends also on the shape of the parts, their weight, and the quality of finish that must be maintained on the external surfaces. While the external surfaces of brass die-castings are much smoother than those of sand castings, heat check-marks develop on the dies with the production of thousands of castings, and therefore brass die-castings are generally not smooth enough to permit satisfactory chromium plating without first tumbling, grinding, and buffing.

If check-marks are not particularly objectionable on the die-castings, the dies can, of course, be used for a much longer period than if the external surfaces of the castings must be of high quality. Some dies have lasted for as many as 120,000 castings, but the average die life may be considered to be about 30,000 castings.

Cooling the Dies and Pre-Heating Before Starting a New Run of Castings.—Good care of the dies is most essential to insure a satisfactory life. The heat of the operation necessitates that the dies be cooled; but if cold water were employed directly on the dies themselves, they would crack; hence, water is circulated through channels which run transversely and vertically through plates immediately in back of the steel die-blocks. It is desirable to prevent the dies from becoming hotter than 600 degrees F., even though the metal being worked has a temperature of almost 1700 degrees F.

Another important point concerning the dies is that no attempt should be made to produce castings when the dies are cold. A gas line is connected to each die-casting machine in such a way that flames can be directed against the face of both the movable and stationary die members before starting a new run of castings, so as to raise the temperatures of the dies to between 300 and 400 degrees F. The same practice is followed each morning before the machines are placed in operation.

In the production of brass die-castings, oxide forms on the die faces. The thickness of the oxide at the end of a day's run may be as much as 0.003 inch. It is the practice to scrape off the oxide at the end of each day and to repolish all surfaces of the die-cavities. To lessen the formation of oxide, it is also the practice during the operation of a machine to swab the face of the stationary die with tallow after every few shots.

Essential Details of Die Design for Brass Casting.—The construction of the dies used in casting brass is similar to

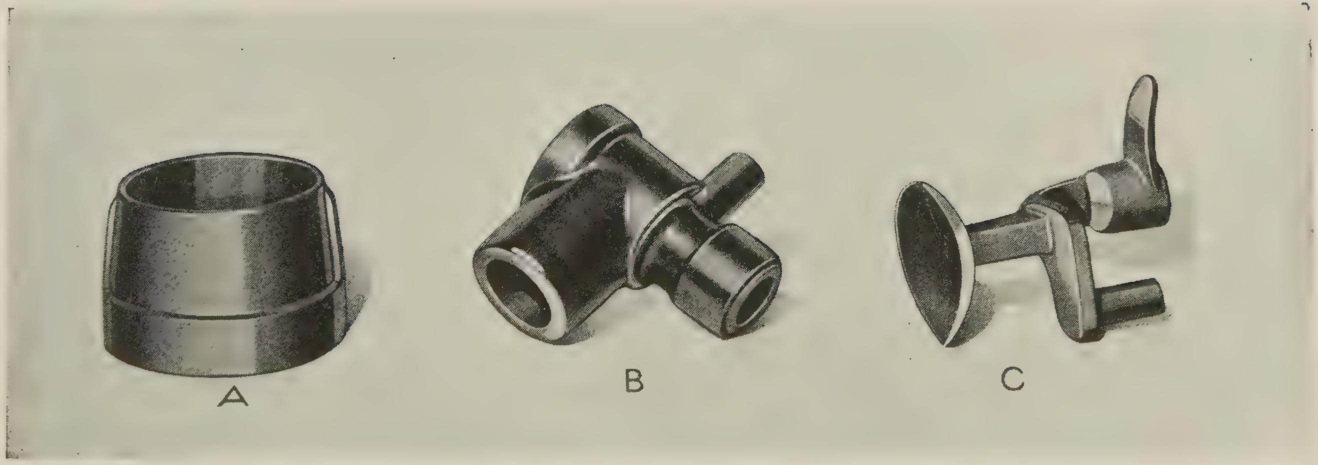


Fig. 9. Some Examples of Brass Die-castings. (A) Hose Coupling; (B) Brass Fitting with Cored Holes; (C) Part Having Bowl-shaped End which is Cast to a Knife-edge

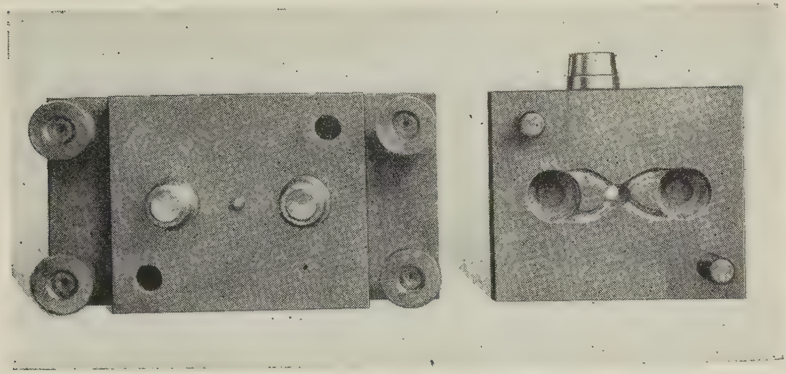


Fig. 10. Dies for Producing the Brass Hose Couplings A, Fig. 9

that of dies for casting other metals such as zinc and aluminum; however, there are certain differences due primarily to the manner in which the plastic metal is forced into the die-cavities. Venting is of importance in the production of some parts. Generally there is sufficient leakage of air between the die faces to enable the ready escape of air from the die-cavities when the plastic metal is forced into them. The gating depends upon the nature of the piece being cast and upon the number of cavities in the dies. When castings require a shank, the dies can often be so designed that the shank will serve as a gate. On such castings no separate trimming operation is required on the shank since it is cut to length by the ejector in the compression chamber of the die-casting machine. Cores and side walls of die-cavities are commonly made with a draft amounting to one-quarter of a degree. Threads as fine as ten per inch can be cast externally. They generally require a finishing operation if a close fit is necessary.

Fig. 10 shows a simple set of dies which are used for producing hose couplings of the type seen at *A*, Fig. 9. These couplings are 1 15/16 inches maximum outside diameter by 1 3/8 inches long. They have a wall which varies in thickness from 1/16 to 1/8 inch, the couplings being tapered both inside and outside. Two plugs on the movable die

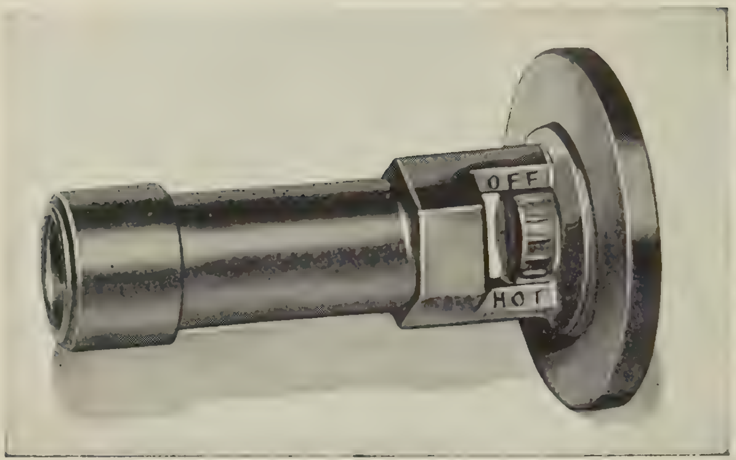


Fig. 11. Brass Die-casting 4¾ Inches Long with Cored Hole Extending through the Cylindrical Part. Weight, 27 Ounces

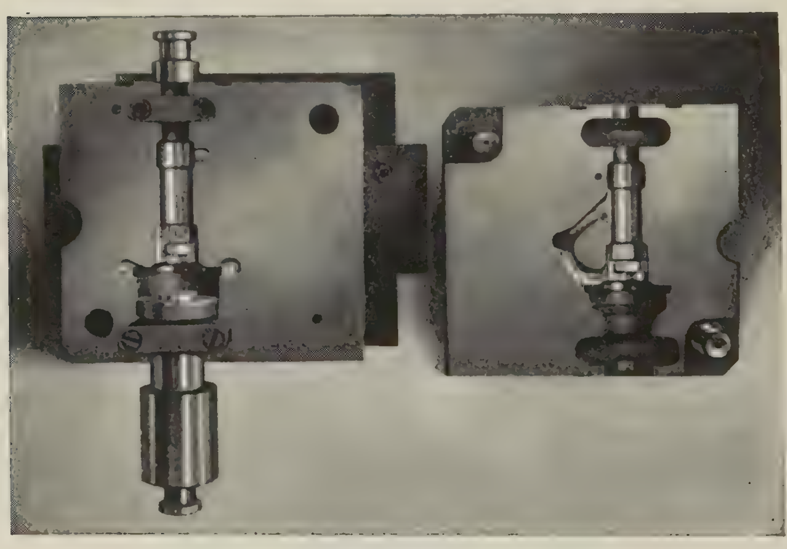


Fig. 12. Dies for Producing Casting which is Shown in Horizontal Position in Fig. 11. Hydraulic Core-pulling Heads Operate the Sliding Cores on the Movable Die

seen at the left in Fig. 10 enter the cavities of the stationary die at the right to serve as cores for these parts. These two cores project through a plate which operates to strip the die-castings from the plugs as the movable die reaches the end of its opening stroke. This stripping action is effected through adjustable horizontal bars on the sides of the die-casting machine.

It is the practice to make the working end of all cores readily replaceable because these ends become red hot in operation, and, as a consequence, often have a short life. Two pilot-pins on the stationary die enter holes in the movable die as the dies are closed, so as to insure that the two die members will be registered accurately for each operation. It will be seen that two gates lead to each of the die-cavities in the stationary member, so as to insure that the plastic metal will completely fill the deep narrow cavities before it starts to solidify. The length of the gate opening at the point where it connects with a die-cavity depends on the nature of the casting. It is the practice to make the width or the height of the gate at the edges of a cavity about 0.030 inch.

Die with Two Vertical Sliding Cores Operated by Hydraulic Core-Pulling Heads.—A brass die-casting of more than ordinary interest is illustrated in Fig. 11. This piece is about 4 3/4 inches long by 3 inches in diameter at the flange end. It has a cored hole in the opposite end 15/16 inch in diameter by 3 inches long. There is also a small rectangular opening completely through the piece adjacent to the flange. In addition, two recesses and a center hole are cored in the flange end. The dies designed for the production of this casting, which weighs 27 ounces, are shown in Fig. 12.

Hydraulic core-pulling heads are employed to operate sliding cores on the movable die for producing the cored hole and the recesses in the opposite ends of this casting.

The dies were photographed while resting on a bench in the same manner as they are mounted in the machine—that is, with the hydraulic core-pulling heads vertical. The lower core-pulling head is shown in place, but the upper head was removed at the time the picture was taken.

The top head is used to operate the long core and obviously this core must have a movement slightly greater than 3 inches in order to release the die-casting. The core at the bottom of the dies which produces the recesses and center hole in the flange has a movement to about one inch. It will be seen that projections on the movable and stationary die faces seat against each other to form a core for producing the rectangular hole that extends through the casting near the flange end.

Both core heads consist simply of a hydraulic cylinder with a piston to which the core is attached. Pressure is admitted into the cylinder while the dies are closing to position the cores for the casting operation and when the dies are open to release the die-casting from the movable die. Five ejector-pins on the movable die force the casting from the die after the cores have been withdrawn.

While these hydraulic core-pulling heads are mounted at the top and bottom of the die shown, they could also be located for moving cores at an angle with respect to a vertical center-line. They could not, however, be positioned horizontally on these machines because of the large-diameter bars which run from end to end, but this is not true of the later Polak machines.

The fitting shown at *B* in Fig. 9 is made with a cored hole that runs at right angles to another cored hole which extends the length of the casting. Each of these cored holes is of two diameters. The hole which extends through the entire piece is produced by a hydraulic core-pulling head mounted on top of the die, while the hole at right angles to the first mentioned is formed by a core fixed to the stationary die.

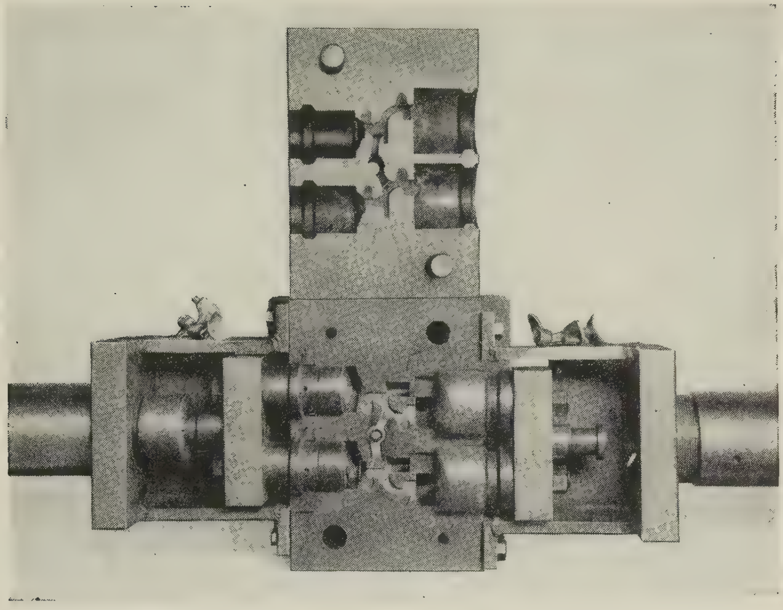


Fig. 13. Dies for Casting Brass Part Shown at C, Fig. 9. Two Castings are Made Simultaneously

The dies shown in Fig. 13 produce two castings at a time. The form of casting is shown at *C*, Fig. 9. It is part of an ice cream dipper, and the bowl-shaped end is cast to a knife-edge to seat a mounted chromium-plated bowl. Two hydraulic core-pullers are required for this die, the upper one being necessary to move a core which forms the cavity at the bowl-shaped end. The lower core-puller is required because of the peculiar shape of the end opposite to the bowl. These cores do not produce any holes. The dies were photographed lying horizontally on the bench, but they are mounted in the die-casting machine with the core-pulling heads vertical.

Although only hydraulically operated and fixed cores have been described, some dies have cores operated through rack-and-pinion mechanisms. These mechanisms are, in turn, actuated by coming into contact with bars mounted on the machine, when the movable die is opened and closed.

Contraction of Brass in Cooling.—In designing dies for brass castings, it should be remembered that the castings contract in cooling about the same amount as brass forgings, which is generally considered 0.010 inch per inch of length or diameter. Holes smaller in diameter than 3/16 of an inch should not be cored, as cores of small diameters will not stand up under the high temperatures of brass die-casting. They will soon heat-check badly and crack off.

Colors of Brass Die-Castings.— The alloys most widely used in brass die-casting, and the cheapest, are yellow in color. Alloys with a high nickel content have a white appearance, thus particularly adapting them for parts to be nickel and chromium plated. If the plating of such parts wears off, the metal beneath is similar in appearance and is not noticed as readily as if it were yellow brass. This is an important factor with many plumbing fixtures, etc.; however, in the case of valves and pipe fittings yellow brass castings are often preferable due to the users having become accustomed to considering them standard.

Melting Temperatures are an Important Factor in Brass Die-Casting.— In a paper presented before the National Metal Congress by John R. Freeman, Jr., of the American Brass Co., the importance of melting temperatures as limiting factors in die-casting copper-base alloys was referred to.

The melting point of copper is 1084 degrees C. (1983 degrees F.), while that of a high brass is about 900 degrees C. (1652 degrees F.), as compared to 327.5 degrees C. (621.5 degrees F.) for lead, 419.4 degrees C. (786.7 degrees F.) for zinc, and 658.7 degrees C. (1217.7 degrees F.) for aluminum. These temperatures are indicative of the casting temperature required for the various types of alloys, the melting points of the alloys being somewhat lower than for the pure metal.

The alloys that can be die-cast commercially are limited only by their melting point and the consequent casting temperature required. At the present time, the higher melting-point alloys cannot be cast, due to the limitations of the die steels available. Brass having a composition of 60 per cent copper and 40 per cent zinc has the lowest melting point of the commercial brasses, and for this reason is widely used in the manufacture of brass die-castings. Other elements, however, are added to obtain certain characteristics more or less peculiar to the die-casting process. The plastic range of the high brasses is quite narrow, but may be greatly increased by the addition of a small percentage of lead, due to the fact that it is unmixable when in the molten condition in brass alloys. Lead also, as is well known, confers machineability upon brass. It reduces markedly the ductility and, in excess, introduces hot-shortness.

Addition of Aluminum to Retard Oxidation of Metal.—In die-casting, the metal must be maintained at the casting temperature in the holding pot for appreciable periods, during which it is uncovered and subject to continual oxidation by the atmosphere. In the plastic or "mushy" state, the oxide formed is not readily skimmed from the surface. The addition of about 0.1 to 0.2 per cent aluminum has been found to retard this oxidation, and appears to be quite generally used both in European and American practice.

Aluminum also reduces the vaporization of zinc in the holding pot and diminishes the deposit of zinc oxide on the die surfaces. Tin is also added. This gives increased fluidity to the alloy in the casting, tends to check the segregation of lead in the holding pot when semi-plastic metal is being used, and increases the corrosion resistance of the final casting.

Die-Casting Aluminum Bronze by Vacuum Process

The vacuum die-casting process to be described is employed in producing aluminum-bronze castings. These castings are generally made from an alloy composed of 89 per cent copper, 10 per cent aluminum, and 1 per cent iron. The composition can, however, be varied slightly to obtain physical characteristics that will adapt the castings to special requirements. In addition to the advantages of high strength and unusual hardness, these aluminum-bronze die-castings offer effective resistance to abrasion and high resistance to corrosion under many adverse conditions.

Principle of the Vacuum Process.—A distinctive feature of the process employed for the production of aluminum-bronze die-castings, is the use of vacuum for drawing or sucking the molten metal into the dies. The principle is exactly the reverse of the one followed in the design of conventional die-casting machines, namely, that of applying pressure to force the metal into the dies. In this patented process of the Aurora Metal Co., Inc., Aurora, Ill., the steel die-casting die is swung into position over the pot of the melting furnace by means of an air hoist and lowered until a gate at the bottom of the die has been immersed several inches into the molten metal. Then a valve is automatically opened to connect a vacuum line to the die. Thus, all the air is drawn from the upper end of the die and the molten aluminum bronze is sucked in through the gate at the bottom. With the gate beneath the surface of the molten metal, none of the impurities in the dross at the top of the pot can enter the die.

There is a steady flow of the molten metal to all points in the die-cavity until it has been completely filled. After the casting has solidified to some extent, the vacuum line is disconnected, the die is raised and swung away from the melting pot, and finally the die is opened to remove the casting. Castings weighing as much as 30 pounds have been produced by this method.

Vacuum for this die-casting process is created by means of a rotary pump. The degree of vacuum required depends upon the height of the die-cavity and the design of the part being cast, that is, whether it is simple or complicated. There must be sufficient vacuum to insure that the stream of metal entering the die will flow unbroken to all parts of the cavity. Perfect vacuum is considered obtained when the barometer reading is about 30 inches of mercury. In this process, the vacuum readings range from 5 to 25 inches.

Melting Temperatures.— Aluminum bronze has a melting point around 1950 degrees F., but in the die-casting process used by this concern, it is cast at temperatures ranging between 2050 and 2300 degrees F. The actual casting temperature depends mainly upon the design of the piece being cast. Thin sections with a small sprue hole require a higher casting temperature than thicker castings with a larger sprue.

With such high casting temperatures, the alloy steel dies used naturally do not have so long a life as when die-castings from zinc, aluminum, or magnesium alloys are produced. Nevertheless, they last long enough to effect real economies when such factors are considered as the quality of the castings, the reduced machining necessary, and the lessened first weight of the castings, as compared with sand castings. Another important advantage lies in the fact that casting rejections are practically negligible with this process, and when they do occur, there is no loss in material, because the scrap can be thrown directly back into the melting pot and used again.

The outer surfaces of the die-casting naturally solidify before the inner portions, because the outer metal is in contact with the cooler surfaces of the die. It is important, therefore, to so design the dies that the thin sections of the castings do not solidify before sufficient molten metal has reached all parts of the die-cavity. This point must be carefully observed, in order to insure castings that are solid throughout.

Risers to Supply Excess Metal and Compensate for Shrinkage.—One or more pockets are always provided at the top of the die-cavity to form risers on the die-casting, and it is important that the metal in these risers be kept liquid until the last. Sometimes it is necessary to place a thin sheet of asbestos around the wall of these pockets to prevent the metal of the risers from coming in contact with the die surfaces and freezing before the die-cavity has been completely filled.

With the metal of the risers remaining liquid until the last, this excess metal can flow back into the die-cavity to compensate for the shrinkage that occurs during the solidifying of the casting. Shrinkage is therefore completely confined to the risers and solid castings are the result. The risers and the sprue are cut off when the casting has cooled, and they are remelted, so that there is no waste of material.

The castings are without blow-holes because the air is withdrawn from the die-cavity, and air cannot enter the gate, due to its immersion in the pot of molten metal. Another important advantage derived from making aluminum-bronze castings in dies is that inclusion of aluminum oxide does not occur in the body metal. This has been one of the most difficult problems in casting aluminum bronze by other methods. However, in the vacuum die-casting method, the small amount of aluminum oxide that is formed on the ad-

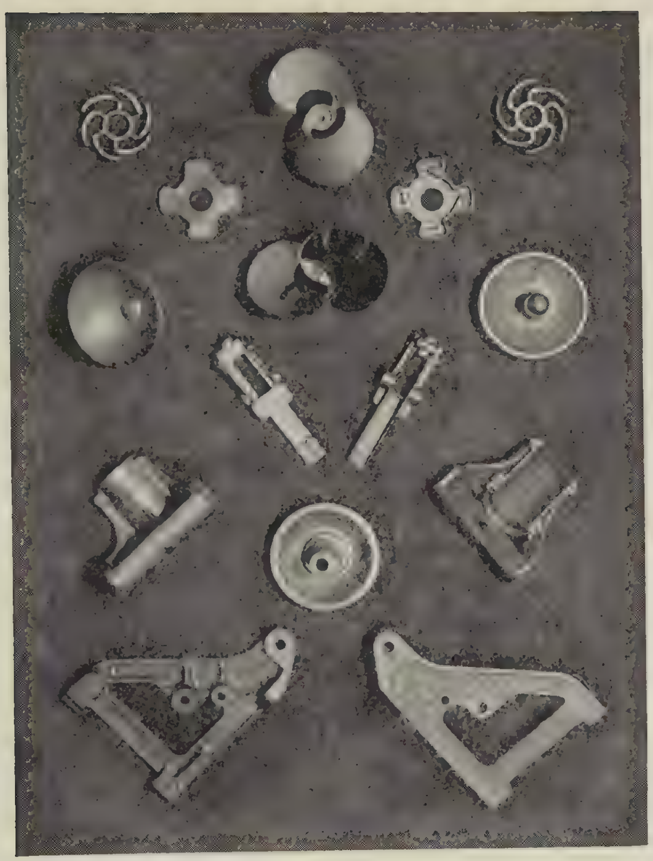


Fig. 1. Die-castings of Aluminum Bronze Made by a Process in which the Molten Metal is Drawn into the Die by Vacuum

vancing level of the metal in the die is deposited in a thin film on the walls of the die-cavity, and therefore is on the outer surfaces of the die-casting, where it can do no harm.

Tolerances equal to about 1/2 of 1 per cent can be easily maintained in most instances on the diameter or straightness of holes, the center distance between holes, and similar dimensions. Thus, for instance, if the diameter of a hole was 0.824 inch, the hole could easily be cored with a total tolerance of 0.0041 inch. Closer tolerances can be maintained, but the cost of the castings increases considerably when extreme accuracy is required.

Uses of Typical Aluminum-Bronze Die-Castings.—Aluminum-bronze die-castings of quite a range are shown on the display board in Fig. 1. In the center at the top of this board is shown an impeller used in an electric dish-washing machine. This impeller measures about 7 inches in maximum diameter and is characterized by long curved blades of unusually thin cross-section, the minimum thickness of the blades being only 3/64 inch. These impellers are die-cast with such a smooth finish and accuracy that only a minimum amount of machining is necessary to prepare them for assembly.

On each side of the impeller are shown centrifugal pump rotors, also used in a dish-washing machine. While light in weight, these rotors have plenty of strength for their purpose and do not wear or corrode. Other examples on the display board are used in applications where strength is important, in combination with resistance to corrosion or abrasion. Spur gears for hydraulic pumps and other applications, as well as gear segments and worms, are cast with ease from aluminum bronze, and they can generally be used without any machining on the teeth.

On all die-castings made by this process, surfaces that must be machined can be provided with a minimum amount of excess stock, in comparison with sand castings. This is a factor of considerable importance, as it reduces the cast weight of the part. For example, die-cast gear blanks sometimes weigh as much as 30 per cent less than sand-cast blanks. Consequently, while the cost per pound is higher for the aluminum-bronze die-casting than for the sand casting, the total cost may be less, because of its reduced weight.

At the bottom of Fig. 1 are shown two brackets that have over-all dimensions of 10 by 7 5/8 inches. These castings weigh about 6 pounds apiece. Fig. 2 shows the die used in

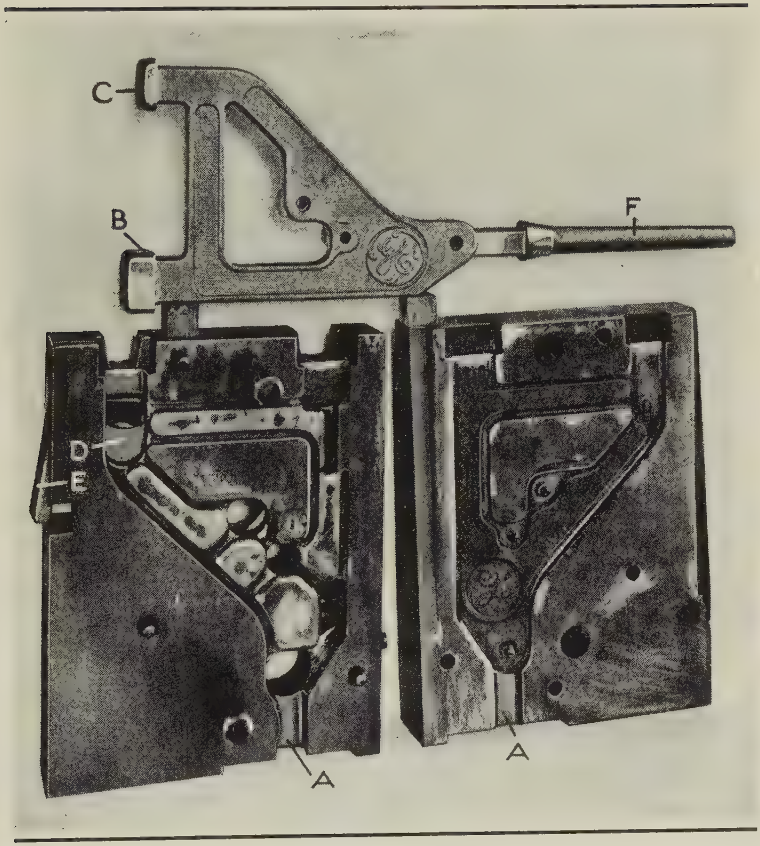


Fig. 2. Die Used in Producing an Aluminum-bronze Bracket Having a Tensile Strength of 85,000 Pounds per Square Inch

producing this part. The sprue hole *A* at the bottom of each die half is about 1 inch square, while the pockets at the top that form the risers *B* and *C* are about 2 inches square.

An interesting feature of this die is the swinging core *D*, which forms a slot in the bracket. This core is swung out of the casting by means of lever *E* to permit the casting to be taken from the die. At *F* is seen the long bar of excess stock that is formed in the gate which is fastened to the bottom of the die.

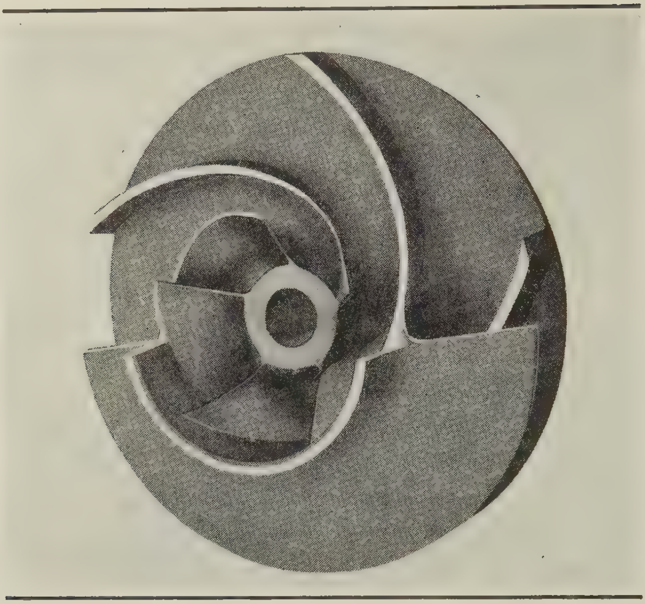


Fig. 3. Pump Impeller of Silicon Bronze Produced in a Die through the Use of a Sand Core

Sand Cores Can be Used in Making These Die-Castings.—Pieces of fairly complicated design can be made by the vacuum die-casting process through the use of sand cores, thus avoiding the necessity of employing moving cores in the dies. This feature of the process also permits the casting of many pieces that could not be made with moving cores as, for example, the pump impeller which is shown in Fig. 3 partly cut away to illustrate the curvature of its vanes.

This impeller is 5 1/2 inches in diameter. The die used in producing it is of comparatively simple design, being made up of the two halves shown at *B* and *C* in Fig. 4. At *A* is the sand core that produces the vanes between the two flanges of the piece, and at *D* is the impeller casting as it comes from the die.

The sand is removed from castings of this type either by

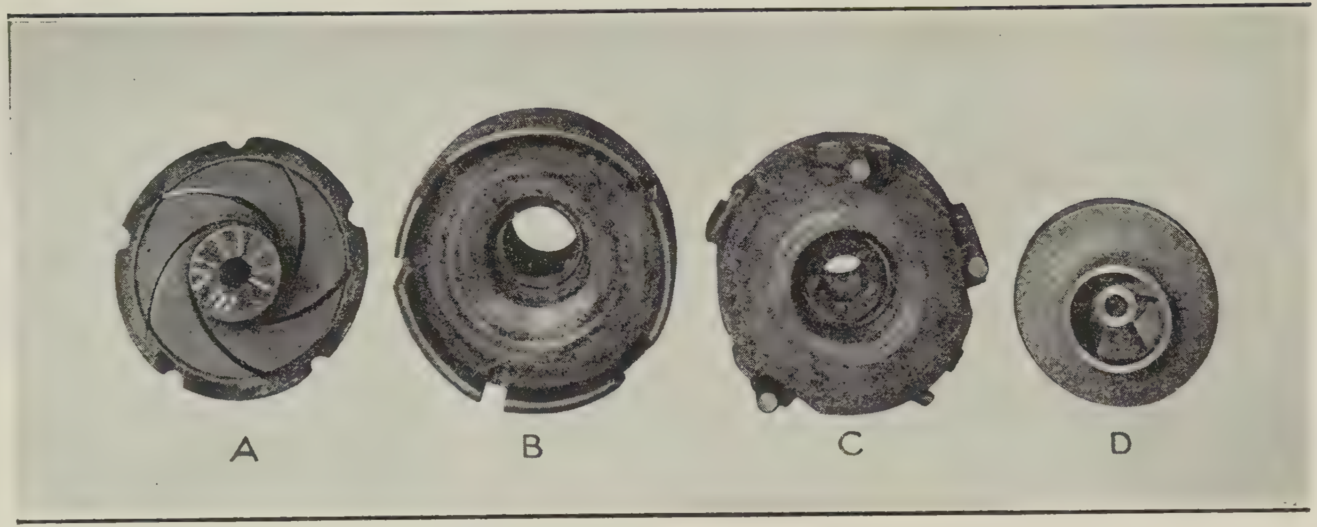


Fig. 4. The Die and Sand Core which Produce Pump Impellers of the Type Shown at D

ordinary means or by sand-blasting. These impellers are cast from a patented silicon bronze consisting of 81 per cent copper, 14 per cent zinc, and 5 per cent silicon. This alloy melts at about 1800 degrees F., but the furnace must be held at a temperature of about 2100 degrees F. to insure that the metal will flow readily into the slots of the sand core which form the vanes.

Castings that Require Inserts of Different Metals.—In this die-casting process, the aluminum bronze can be readily cast around pieces of other metals that are placed in the die in the form of inserts. Thus, for example, castings can be produced that are attached to steel shafts. At *A* in Fig. 5 is shown an aluminum-bronze die-casting with a bronze bushing or sleeve that is cast in place. To the left of part *A* are shown the various members of the die used in producing it. The bronze insert is positioned in the die as shown at *B*, and the steel core *C* is positioned vertically on the pins of the die adjacent to the insert. This is done before the second half of the die and the top at the extreme left are assembled.

The bronze insert used for this part has a lower melting point than the aluminum bronze from which the part is made, but in the casting operation, the aluminum bronze freezes immediately when it reaches the insert and thus enables successful results to be obtained. The two holes seen in the die top permit the formation of the risers to eliminate the shrinkage that occurs in cooling. One of the bosses in the die top centers the insert and two others locate the loose core. The casting made in this die has an overall length of 4 3/4 inches.

When dies are to be used for the limited production of a part, their cost can generally be reduced correspondingly. For example, a manufacturer required only ten small eccentric spur gears of a certain type each year. He supplied a steel sample from which a die was cast of aluminum

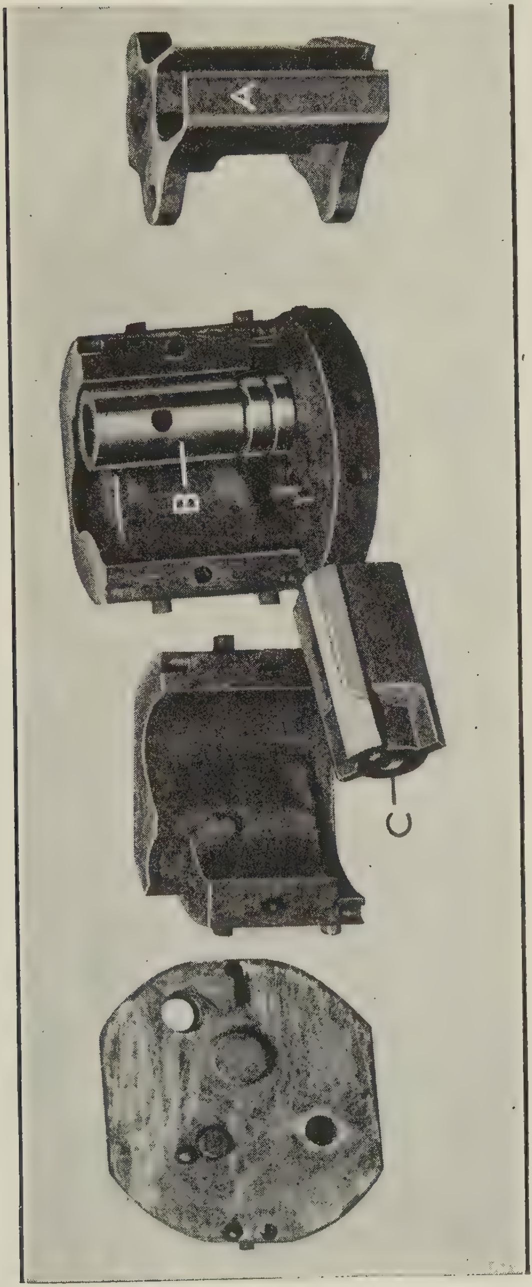


Fig. 5. Die for Producing a Part with a Bronze Sleeve Cast in Place for Use as a Bearing

bronze. This casting was cut in two, mounted in a suitable holder, and has since been used for casting the required gears from aluminum bronze—the same material as the die itself. Eighty gears have been cast in this die and it is still in fairly good condition. Little deterioration has occurred because of the fact that the molten aluminum bronze freezes immediately when it strikes the die surfaces.

Strength and Hardness of Castings.—The aluminum-bronze die-castings have a tensile strength of 85,000 pounds per square inch, as cast, and a hardness of 140 Brinell. By reheating the castings to 1700 degrees F. and quenching them in water, their tensile strength can be increased to as much as 100,000 pounds per square inch and their hardness to 260 Brinell. Even at elevated temperatures, these castings maintain their tensile strength to an unusual degree; at 1000 degrees F. it is as high as 19,000 pounds per square inch.

Unit System of Die-Casting

The general object of a method of die-casting known as the "unit system" is to utilize as far as practicable relatively simple die units in conjunction with a universal holder designed to accommodate several unit die-blocks. The cost of the die units (and the investment in dies) is comparatively low, and production may be comparable to that obtained with multiple-cavity dies. The unit system is a development of the Mount Vernon Die Casting Corporation, Mount Vernon, N. Y.

Dies and Die-Holder of the Unit System.—An important objective in developing this system was the reduction of the large investment required for die-casting dies. With the conventional set-up, low cost per casting often necessitated the use of multiple-cavity dies. Such dies were expensive to make, even when the best modern methods of machining the cavities were employed. It appeared that the only way to reduce the cost of the dies was to find some way of using dies having, in general, only one or two cavities without sacrificing the productive efficiency of the multiple-cavity dies. This has been accomplished by the unit system.

It was found that the majority of dies did not need to be self-contained units, each with its own separate core-slides and ejector parts. To make them in this form required large blocks of die steel and often a great deal of expensive machine work for core-slides and means for actuating them. It became evident that only one pair of small single-cavity die-blocks would be needed for each part cast if several of these small die-blocks were mounted in a universal holder

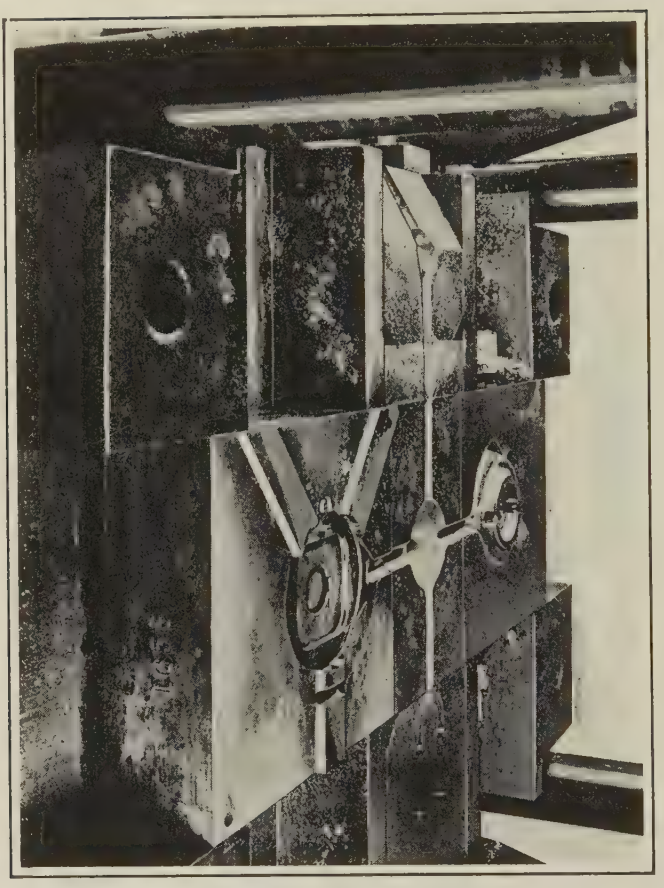


Fig. 1. Rear Half of a Set of Unit Dies and Their Holder. The Front Half is Shown in Fig. 2. Provision is Made in This Instance for Drawing the Core of the Top Die at an Angle to the Parting Face.

A suitable holder was therefore devised, and as a result, the dies now used consist chiefly of single-cavity blocks, usually about 4 or 6 inches square and 2 inches thick, although the dimensions are not necessarily confined within these limits.

The cores are attached to permanent slides in the universal holder. The ejector-pins are mounted on a small plate which is clamped to the ejector-plate of the machine, and require no other guiding means; consequently, all the

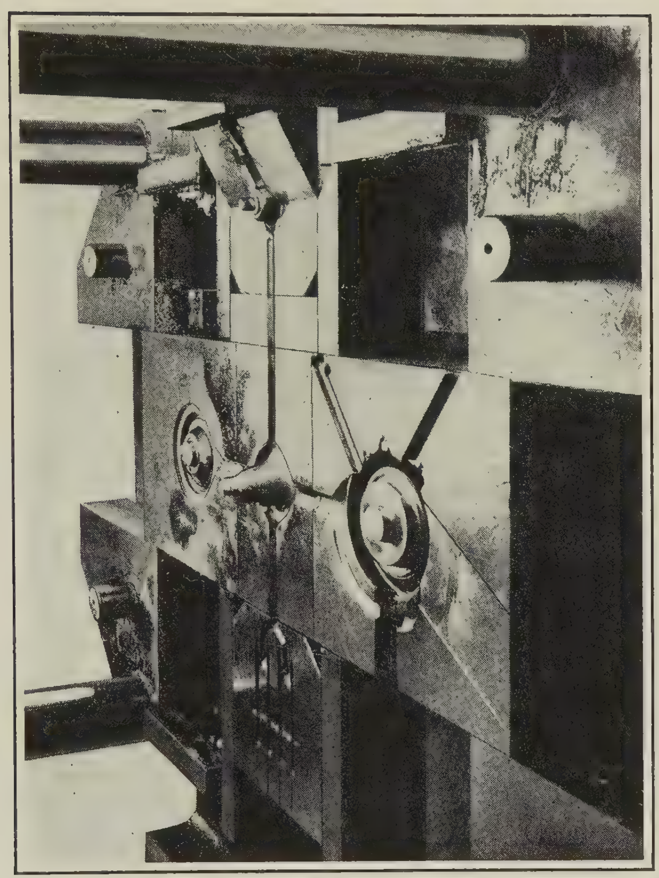


Fig. 2. Front Half of a Set of Four Dies in a Universal Holder Used in the Unit System. Four or More Die-castings can be Made at One "Shot" with Such Equipment

die equipment—aside from the blocks containing the cavities, which, in themselves, are relatively inexpensive—are the simple core and ejector parts required.

By combining in a universal holder four or more dies, no two of which need be for the same piece, each die usually having only one or two cavities, the production economies of multiple-cavity dies are realized without the cost of machining multiple cavities. By these means, the initial cost of the dies can frequently be decreased as much as 30 to 70 per cent, depending on the character of the castings to be made. Figs. 1 and 2 show the rear and front holders of dies for producing four different parts. If necessary, arrangements can be made for drawing cores from four directions, or even at an angle to the usual drawing directions.

Quick-Change Feature of Die Units.—The possibilities of more economical production do not end with the die itself. As all the parts of the die are made to fit the universal holder, the dies can often be changed in five minutes, whereas in ordinary practice, from two to four hours may be required, during which time the machine remains idle. This saving in time is of special significance when orders are small and runs for a given die are correspondingly short. The unit type dies have the advantage of being small and relatively light in weight. Thus, one man can handle the dies easily and the storage space required is very small, compared with that required for ordinary dies.

Unit Die System Permits Economical Use of Larger Machines.— Perhaps the greatest economy effected by the unit system relates not to the dies themselves, but to the method of using them in multiple arrangements so that four dies are filled simultaneously in the same time, or perhaps in an even shorter time, than would be required for filling an ordinary die, since a large and fully automatic machine is used.

To effect this saving, the half for holding the blocks forming the die-cavities is designed not to accommodate a single set, but as many as four sets of dies. Any one of these dies can be changed without affecting the set-up of the others or of the machine as a whole, and the arrangement is such that all the dies are filled at one "shot" of the machine; consequently, instead of producing one casting, or a set of castings in the case of dies having multiple cavities, four castings are produced at each shot. As the type of machine employed is capable of about 1500 shots per eight-hour day, it follows that with four dies in use, 6000 castings can be turned out in this period. A machine is readily operated by one man, and hence, the labor charge is correspondingly low.

Why the System is Particularly Efficient in Odd-Lot Production.—It is not necessary that a run of the same number of pieces be made from each of the dies in use, for any one of the dies can be changed in a few minutes without disturbing the set-up of the other dies. What this means to a plant serving a large number of customers, any of whom may require a run ranging from a few hundred up to many thousands of castings from one die, can well be imagined. When short runs are common, and conditions such that customers order in "hand-to-mouth" quantities, the advantages are great, both to the customer and the manufacturer.

If, at any time, the orders on hand for different pieces happen to be less than the die capacity of a given machine, a blank die can be put in place of one or more dies, so that the other dies will still be productive. It is advantageous, however, to keep all the die spaces filled with dies from which castings are required, since, if any are blanked off, the hourly production rate is correspondingly decreased.

Features of Die-Holder Construction.—Coming now to a more specific description of the die frame or holder, which might be adapted to almost any power-operated die-casting machine, it will be seen from Figs. 1 and 2 that this assembly consists of two major plates. These plates are about 20 inches high, 28 inches wide, and 4 inches thick and are attached to the front and rear heads of the machine. In closing the dies, the heads are moved toward each other by a hydraulically operated toggle mechanism. In the holders shown there is provision for two 6-inch and two 4-inch dies, but in alternative arrangements for dies of larger size, space for only two dies is provided. It will be

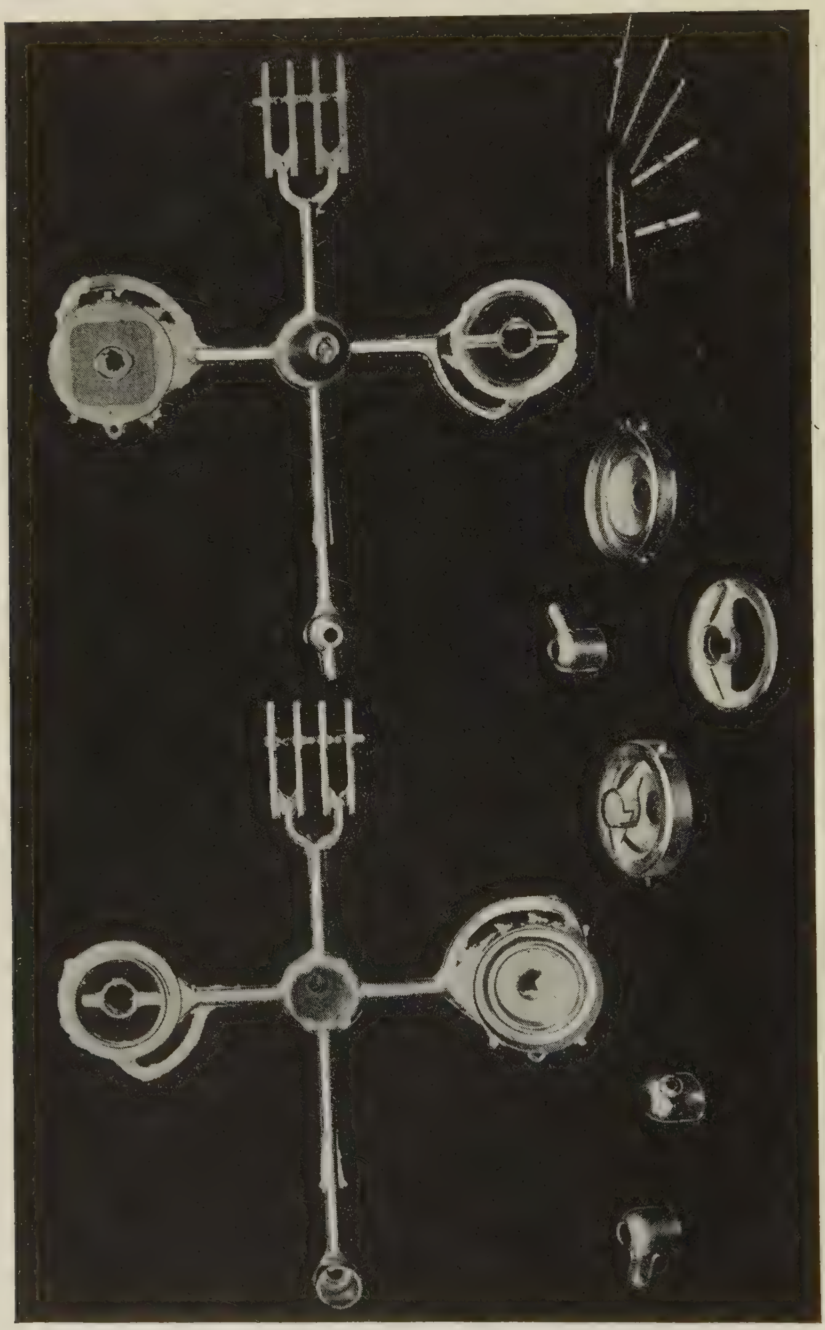


Fig. 3. Two Views Showing Both Sides of a Gate Made up of Four Different Kinds of Parts Just as They Come from the Dies Shown in Figs. 1 and 2. In the Lower Part of the Illustration, the Same Pieces are Shown after the Fins Have Been Removed. An Internal Thread is Cast in the Largest Casting by the Use of a Removable Core. The Small Bar-shaped Pieces are Only 1/32 Inch Thick

apparent, however, that various arrangements involving the same principle can be adapted to meet the requirements of the particular machine and size or placing of the dies.

Each of the die frames in the four-die machine is provided with a central gate-block. The block in the rear plate has a conical opening which registers with the nozzle of the pot containing the molten metal being used. Mating with this is the block in the forward plate which has a conical projection that enters the hole in the rear gate-block when the dies are closed. This projection is made hollow for water-cooling, and clears the hole in the rear block, so that the molten metal has space to flow between the hole and the projection into the annular opening surrounding the hole and thence outward through four cylindrical gates, each of which mates with the gate of one of the four dies. The gate openings for the 6-inch dies are slightly larger in diameter than for the 4-inch dies.

Opposite each of the four sides of the two gate-blocks is a slot that measures 4 inches and 6 inches across and is 2 inches deep. Into these slots the die-blocks fit, their faces at the parting line being flush with the parting between the two gate-blocks. The forward half of each die is fastened to the forward plate, and the rear half to the rear plate. The slots for holding the dies are only half as deep as the plate, but the metal under the slot is mostly cut away, so that the die rests only against a ledge and its back face is almost clear, allowing the ejector- and core-pins to enter as required. Although the thickness of the die halves is normally only 2 inches, a part of the die can be allowed to project through the opening below the slot if a deep cavity is required.

The die-blocks are made of a standard 4-inch or 6-inch width, so as to fit the corresponding slots, but they can be almost any length, parallel to the slot, that the plate can support and hold tight at the parting line when the dies are closed.

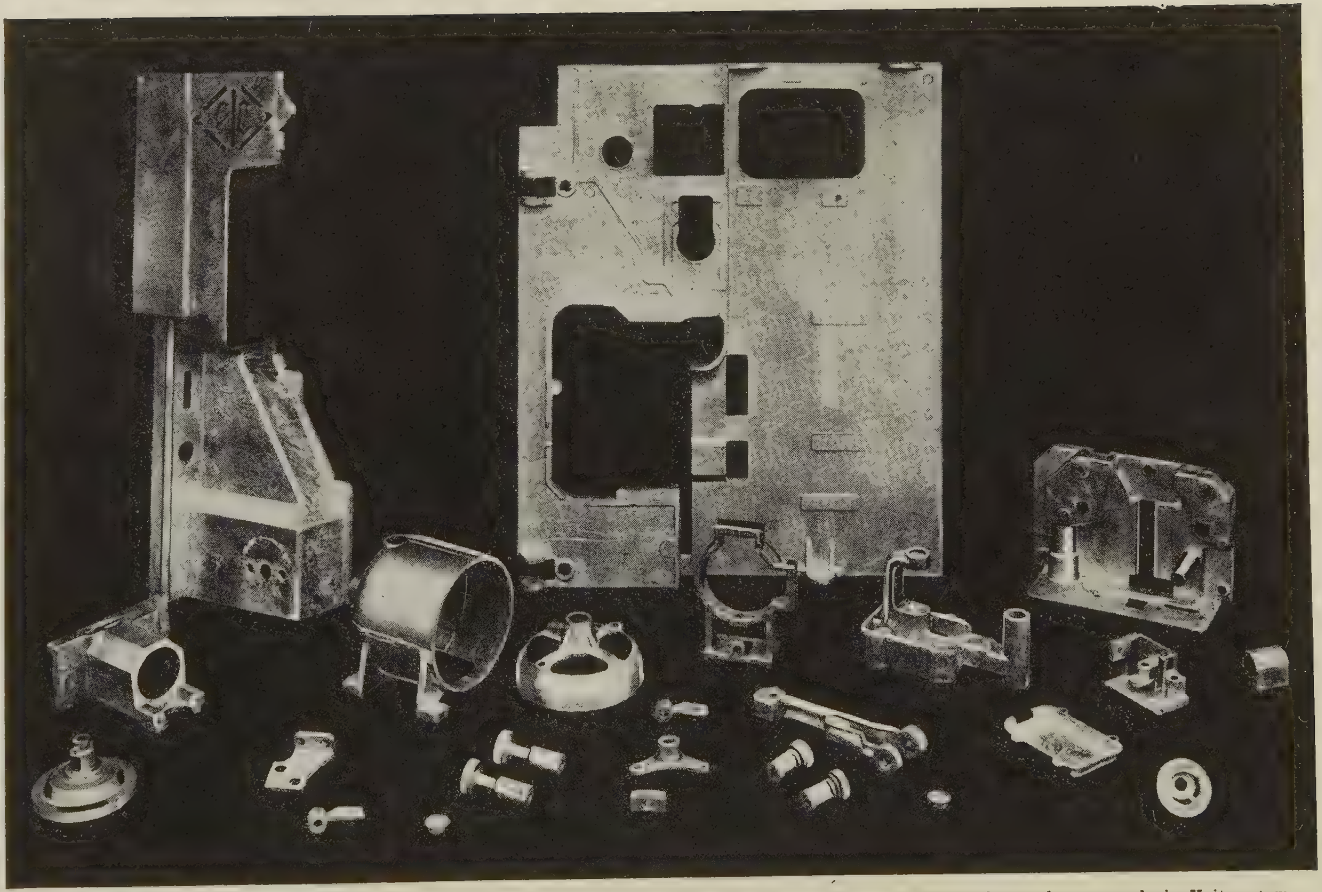


Fig. 4. Group of Die-cast Parts for Picture Projection Machine. All but the Largest Pieces in the Background were made in Unit-system Dies. Many of These Parts Have Several Cored Holes or Cavities Produced by Cores that were Drawn Either Parallel to or at Right Angles with the Parting Face of the Die

Methods of Operating Ejector-Pins and Cores.—Ejector-pins and cores that are pulled parallel to the axis of the machine, that is, at right angles to the parting plane, are operated through a rack and pinion device in conventional fashion, the cores by stops engaging with a lever on the pinion shaft, and the ejector-pins by a hand-operated lever.

Cores to be pulled in a plane parallel to the parting plane are actuated by vertical core slides that fit into 4-inch slots at each side of the central slot for the 4-inch dies. These slides are actuated, in turn, by square-section bars fixed to the machine. Inclined surfaces on the bars contact with rollers on the slides, so that the slides are reciprocated as the heads of the machine move longitudinally. These slides serve only the 6-inch dies; hence castings that have transverse cores are confined to the 6-inch slots. Cores are sometimes operated at an acute angle to the axis of the machine when this is required.

Since all essential outside dimensions of the die-blocks are held to a standard that will fit the corresponding recess in the holder, the dies are quickly and easily changed. The holders are accurately machined and firmly attached to the heads of the machine, which are reciprocated on close-fitting hardened bushings that maintain accurate alignment; hence it is not even necessary to have dowel-pins in the two halves of the die. These halves are simply set into recesses and locked with taper pins that hold them securely and insure tight joints at the parting. Slides carrying cores and plates with cores and ejector-pins are placed with equal facility, so that set-up and removal operations are easily and quickly performed.

Aluminum-base castings, as well as zinc, are made by the unit process, when light weight and other considerations demand it, but the higher temperatures required necessitate the use of alloy steel dies, which are more expensive than the forged machine steel used for zinc-base castings. In other respects, however, the method in ques-

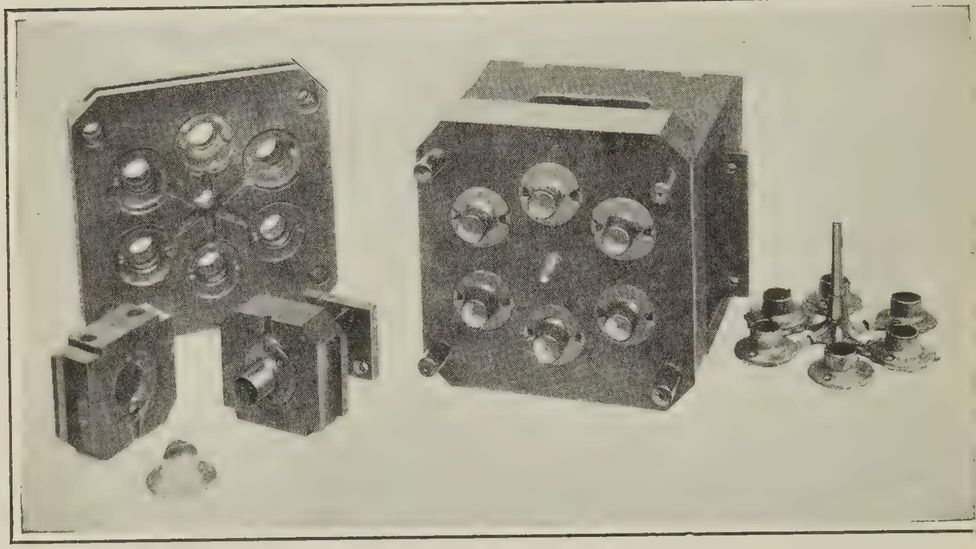


Fig. 5. A Pair of Single-cavity Dies Used with the Unit System, and a Pair of the Older Type Dies which Required Six Cavities to Make their Operation Profitable. The Single-cavity Die Used Simultaneously with Other Unit Dies is More Economical in Production and Much Less Expensive to Make

tion is of equal utility and makes for greater economy, whether the castings are of zinc or aluminum.

Limitations of Unit System.—It is not claimed that all die-castings lend themselves to production by the unit system. Castings with exceptional core work or those of quite large size may require special treatment which cannot be readily applied with the standardized universal holder used with the unit-system dies. With a very large die it may not be feasible to fit more than one die into a machine at one time, and in such cases, some of the advantages of the unit system may have to be sacrificed. When many large dies are in fairly regular use, however, and the core work is not unusual, it is still possible to make material gains in die construction by using a universal frame, so that each die does not have to be a self-contained unit with its own core-slides and core-actuating mechanism and does not have to be used alone in the machine.

Die-Casting Cast Iron

A process for die-casting cast iron was originated some years ago by Samuel Price Wetherill and developed under his supervision by the Wetherill Engineering Co., Philadelphia, Pa. This process, although not actively used in recent years, is of some interest in that it indicates one of the lines along which die-casting has been developed. The description which follows was published at the time that the process was in use.

The cast-iron die-castings produced by means of the Wetherill process are the same chemically as sand castings, but physically they show many improvements. Their structure is unusually close grained and uniform throughout, having the appearance of electric furnace iron. The result is that die-castings of 2X foundry iron (ordinary pig iron), as shown by many tests, have an average tensile strength of 53,000 pounds per square inch—approximately 20,000 pounds per square inch greater than that of average cast iron. Blow holes, due to shrinkage, do not exist.

The improved physical properties of cast-iron die-castings are due to a large extent to the close control of the molten metal, the high temperature at which it is cast, and the method of forcing it into the dies. Ordinary 2X foundry iron is always die-cast at a temperature between 2700 and 2750 degrees F., whereas in the foundry sand castings of this analysis are generally poured at temperatures ranging from 2400 to 2600 degrees F.

Another important advantage of cast-iron die-castings is that their surfaces are so smooth as to eliminate the necessity of machining in many instances and tumbling entirely. The machineability of cast-iron die-castings is such, however, that parts can be readily drilled, threaded.

etc., when such operations are required. Cast iron can be cast in dies to much sharper corners than is possible in sand casting and specified dimensions can be easily held within plus or minus limits of 0.005 inch. By using steel cores, sand can be completely eliminated from cast-iron die-castings. In addition to the advantages that have already been mentioned, the die-casting of iron castings is an operation of unusual cleanliness in comparison with sand casting.

Examples of Cast-Iron Die-Castings.—The Wetherill die-casting process is applicable not only to 2X foundry iron but to every other mixture that has so far been attempted. For instance, castings containing 5 per cent nickel and others of large silicon content have been produced. Fig. 1 shows typical cast-iron die-castings made with the new process by the first commercially operated equipment, which is installed at the Alan Wood Steel Co., Conshohocken, Pa. All of the castings produced by that company are of 2X foundry iron.

At *A* is a valve stem that is about 14 inches long over-all and 5 1/4 inches in maximum diameter. This part has a weight of 35 pounds. The large rectangular hole through the tapered section was produced by using two solid steel cores which abutted each other in the center of the dies.

At *B* is shown a 4-inch valve body and at *C* a radiator section 17 inches long by 5 inches wide. Sand cores are used for both of these parts to obtain the internal openings. Pipe flanges of the type shown at *D* are produced four at a time in a multiple-cavity die. This flange is 9 inches in outside diameter, has a 4-inch cored hole produced by a steel core, and weighs 13 pounds.

The large diameter disk at *E* is a piston for an air compressor. It measures 15 inches in diameter by 2 inches thick, and weighs 96 pounds. A tapered core produces the center hole. At *F* is a 10- by 16-inch pipe flange weighing

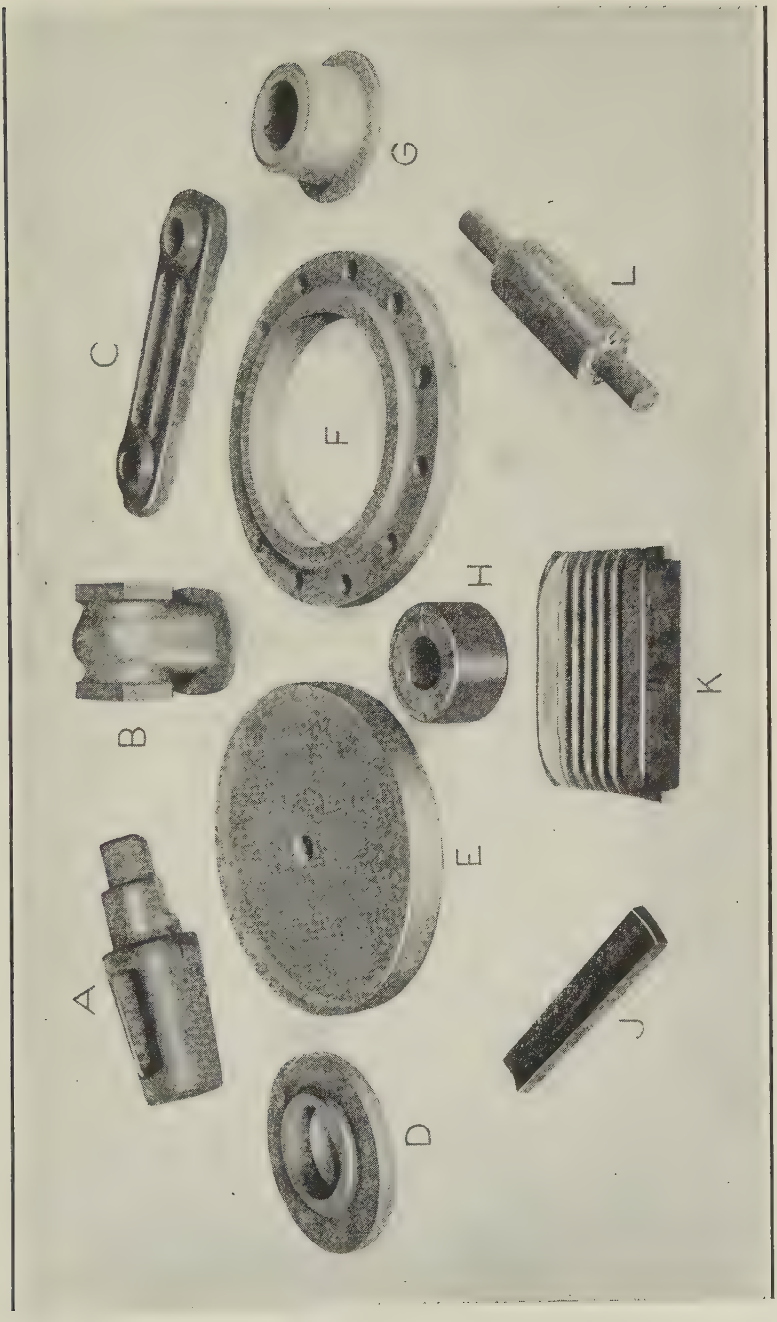


Fig. 1. Variety of Iron Castings That Have Been Produced in Dies by the Application of Low Air Pressure. These Examples Range up to 96 Pounds in Weight

40 pounds. The small holes are drilled in this flange and the threads machined.

Cast Iron Die-Cast on Steel Inserts.—The example shown at *G* (Fig. 1) is of especial interest because it is cast with an insert of seamless steel tubing that is placed in the dies instead of a core. This tubing serves as an outer race for a roller bearing when the part is placed in service. No machine work at all is required in order to accommodate the bearing. The part is a flanged pallet wheel of a type used extensively around blast furnaces. It is chilled in die-casting to give it long-wearing external surfaces. The wheel is 6 1/2 inches in maximum diameter by 3 1/2 inches in width, and weighs 13 pounds. At *H* is shown another pallet wheel without a flange.

The example seen at *J* is a weighing-scale bar that must have extremely hard chilled surfaces. In addition, the part is of a curved design and tapers in all directions. The edges must be true and sharp. At *K* is shown a thin ribbed part that is cast with a flat steel insert in the one end. Example *L* is a pump rotor that is produced by die-casting cast iron around a steel shaft.

Equipment for Die-Casting Cast Iron.—There are several essential differences between the Wetherill die-casting process for cast iron and the conventional methods of die-casting non-ferrous metals. First, in die-casting cast iron, a pressure of only 20 pounds per square inch is employed to force the metal into the dies. Another important difference is that, instead of using expensive dies made of high-grade alloy steels, this process requires only cast-iron die-blocks fitted with simple liners of cold rolled steel that are shaped to suit the contour of the pieces to be cast. These liners are comparatively inexpensive and can therefore be provided in quantities for convenient replacement. When castings are not chilled, the liners cool slowly with the castings.

The equipment, Fig. 2, used in die-casting cast iron is of comparatively simple design. It involves the use of a crucible *A*, Fig. 3, which is made of Syn Carb, a product of the Ross Tacony Crucible Co. of Philadelphia. Crucible *A* is seated as shown at *B* in a half-crucible made of the same

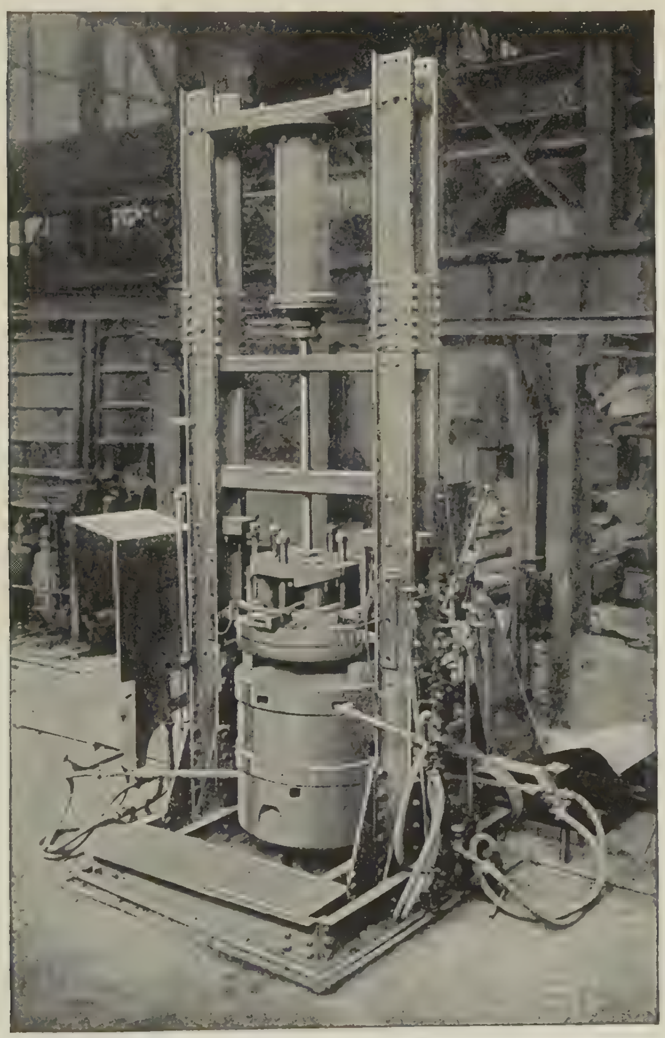


Fig. 2. General View of Apparatus used for Die-casting Cast Iron

material and on two circular blocks *C* that are also Syn Carb. Crucible *A* in the machine which is shown in Fig. 2 has sufficient capacity for holding 450 pounds of molten metal.

Extendng into the crucible is a sleeve *D* which is supported by the crucible lid *E*. Fitted into the upper end of the sleeve is a nozzle *F* through which the molten cast iron is forced into the dies. The hole in the nozzle is 1 1/2 inches in diameter. Lid *E* is made of Syn Carb, while sleeve *D* and nozzle *F* are made of silicon carbide. The crucible and its component parts are enclosed in a steel shell *H* which is 42 inches in diameter by about 41 inches high. Refractory material is filled in between shell *H* and the crucible unit.

Four openings *J* are provided through the refractory material into which oil or gas burners are inserted for heating the crucible around its lower portion and for heating nozzle *F*. In each die-casting operation the die gate is seated firmly on the silicon-carbide plate *L* and thus by heating the nozzle, there is always the assurance that the molten metal enters the dies at the desired temperature.

The crucible is loaded with molten cast iron through the opening *M* in a manner to be later described. Then a 6-inch plug is fitted into the recess in the upper end of this opening, an asbestos gasket being used to insure sealing of the joint. An air line is connected to a fitting on the plug. This air line applies a pressure of 20 pounds per square inch directly on the molten metal for forcing it upward through sleeve *D* and nozzle *F* into dies for each die-casting operation.

When pressure is applied on the molten cast iron, some of it tends to pass between the joint formed by the upper edge of crucible *A* and the recess in the bottom side of lid *E*. To prevent this from occurring, a 1-inch pipe *N* is provided around the upper end of the crucible. Air at room temperature is constantly blown through this pipe with the re-

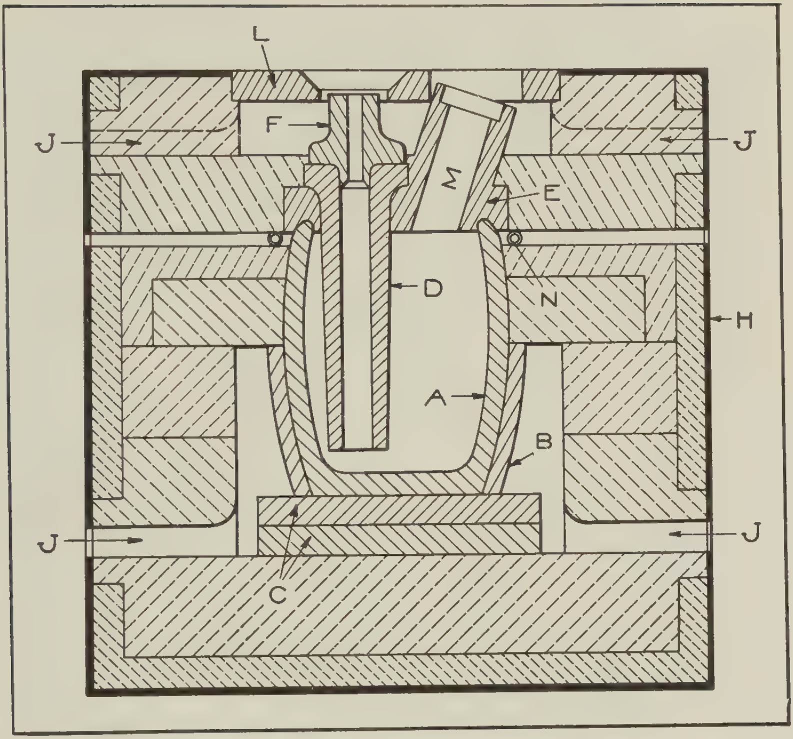


Fig. 3. Cross-sectional Drawing Showing the Crucible in which the Molten Cast Iron Is Held at the Casting Temperature and the Nozzle Through which It Is Forced Upward into the Dies

sult that any molten metal escaping between the crucible and the lid is immediately "frozen," thus sealing the joint against the loss of cast iron.

How the Die-Casting of Cast Iron is Done.—The crucible unit which has just been described is installed, as shown in Fig. 2, between two tall structural uprights. Attached to a tie-bar that connects the upper ends of these uprights is an air cylinder. The piston rod which extends from this cylinder is connected to the upper die of the die set in use, thus providing a means of raising and lowering the dies pneumatically with respect to the crucible unit, and also of opening the top die from the lower die.

Prior to each operation, a 1/4-inch asbestos gasket is placed in seat *L*, Fig. 3. Then the die unit is lowered on this gasket by admitting air into the overhead cylinder, a pressure of 100 pounds per square inch being applied to feed the dies into position and to hold them securely during the operation. Stops regulate the down position of the dies so as to guard against damage to the crucible parts. It is the practice to lower the die units until the asbestos gasket between the gate and seat *L* has been compressed about 1/8 inch and the joint at this point thus effectively sealed.

A valve is then opened to admit air pressure through the plug that closes the upper end of opening *M* in the crucible lid. The molten cast iron then rises upward through sleeve *D* and nozzle *F* to all points in the die-cavity. The cast iron solidifies quickly around the walls of the steel liners that form the die-cavity, but remains molten in the center of the casting and in the vicinity of the gate until near the end of the operation. This insures castings that are solid throughout. Upon the release of the air pressure after a predetermined interval, the molten cast iron in the gate and nozzle runs back into sleeve *D* and the crucible. It requires only about 45 seconds to cast, say, four castings weighing 15 pounds each. The dies are so designed that castings can be chilled when desired. One of the secrets of success in the die-casting of cast iron is the heating of nozzle *F* so that the metal does not solidify close to the gate until after it has solidified at all other points in the die-cavity.

While the crucible of the machine illustrated has capacity for 450 pounds of molten cast iron, it is feasible to cast only about 375 pounds in one operation. A single casting can be produced at a time, or a number of castings. For economy, at least 50 pounds of metal should be cast in one operation of the machine here shown, and each casting should weigh not less than 5 pounds. The machine, Fig. 2, is equipped with the set of dies that casts four pipe flanges of the type shown at *D*, Fig. 1, simultaneously.

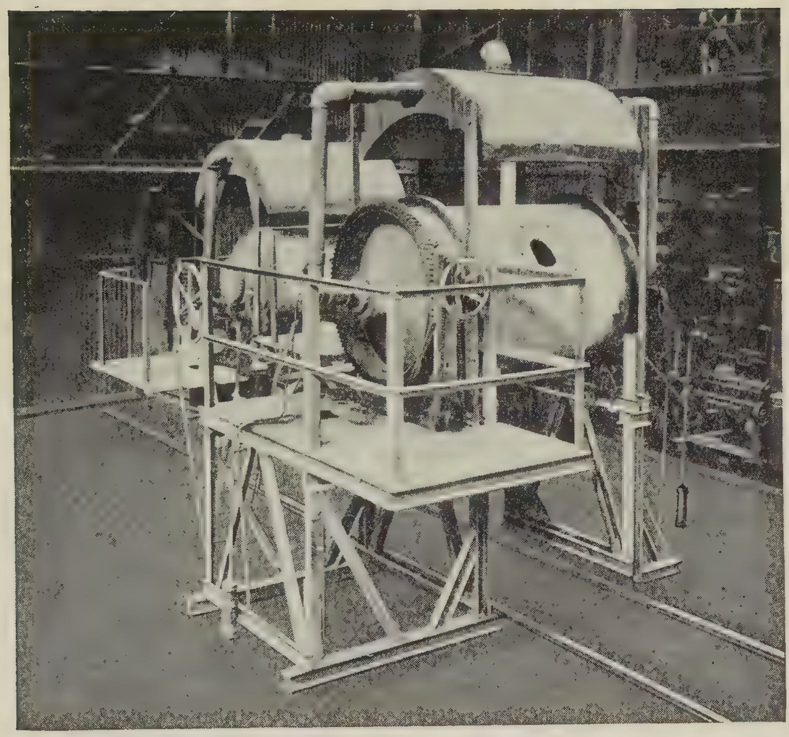


Fig. 4. Rotary Oil-fired Furnace which Supplies Molten Cast Iron in Sufficient Quantity for the Economical Operation of Cast-iron Die-casting Machines

The Melting Furnace Used for Cast-Iron Die-Casting.—One of the important requirements in the economical die-casting of cast iron is a constant supply of molten metal. Whereas in the ordinary foundry the pouring of iron is confined to about two hours in mid-afternoon, after the day has been spent in preparing molds, the die-casting machine is ready at all times for the production of castings. The cupola furnace of the ordinary foundry would not meet the requirements of die-casting cast iron.

To supply molten cast iron in sufficient quantity for economical die-casting, the Wetherill Engineering Co. developed a rotary furnace of the comparatively simple construction shown in Fig. 4. This furnace is oil-fired at both ends of the axle. Preheated air is mixed with the oil where it enters the furnace. The air is heated as it passes through the overhead tank that is supported above the furnace. This tank is heated when the furnace is first started up by allowing heat to escape through the pouring hole, the furnace being positioned with the pouring hole pointed upward and uncovered. About 900 cubic feet of air is supplied to the furnace per minute at a pressure of from 16 to 20 ounces per square inch.

After this furnace has been charged with pig iron or other iron of the desired analysis and the melting operation started, the furnace is revolved once every 15 minutes. From a cold start, this furnace will supply within two hours a ton of 2X foundry iron at a temperature of 2950 degrees F. Approximately twenty-four gallons of crude oil are consumed per hour. One of the important structural features of the furnace is a patented lining that is said to be practically indestructible.

Unusual care is taken to prevent oxidation of the molten cast iron as it is transferred from the rotary furnace to the die-casting machine. For this purpose use is made of a ladle that is identical in design to the unit of the die-casting machine illustrated in Fig. 3. When the metal is emptied into the transfer ladle, it is completely sealed from the atmosphere. The molten cast iron is in turn transferred to the die-casting crucible by applying air to the transfer ladle in the same manner as used to force the metal into the die-casting dies. The transfer ladle is mounted on a carriage that runs on tracks which extend from the rotary furnace to the die-casting machine. One end of this carriage may be seen extending to the right in back of the die-casting machine in Fig. 2.

Dies Used in Die-Casting Cast Iron.—The dies used in die-casting cast iron are comparatively simple in construction. In many cases, the part is formed within liners of

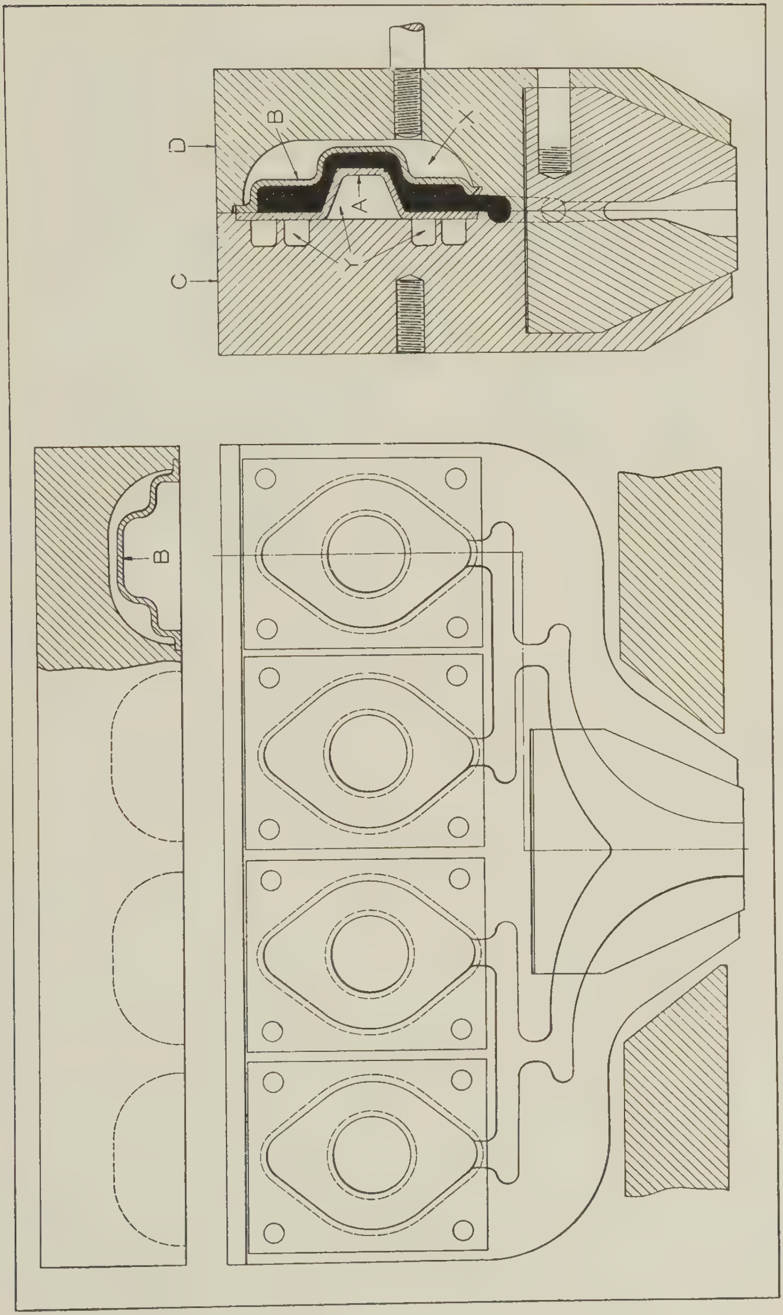


Fig. 5. A Four-cavity Die Designed for the Production of Small Cast-iron Die-castings. The Drawing Illustrates the Method of Employing Steel Liners to Form the Die-cavities

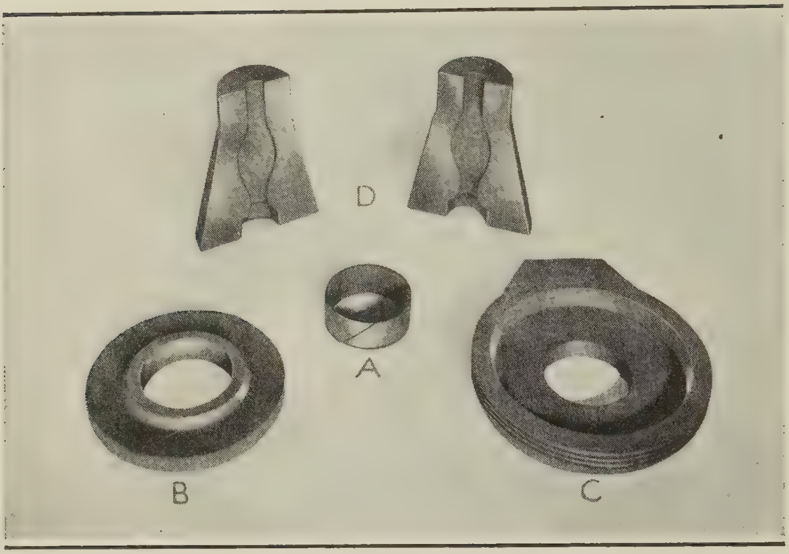


Fig. 6. The Die Parts for Die-casting a Pipe Flange Consist Simply of Two Split Gate Members, Two Cast-iron Die-blocks, a Collapsible Core and Two Steel Inserts which Are Not Shown

cold rolled steel shaped to suit the contour of the part. There is a liner in the upper die and another in the lower die which register together to form a cavity. In Fig. 5 is shown a set of dies that illustrates the basic principle on which the dies used in the Wetherill process are constructed. However, these particular dies were designed for a machine smaller than the one shown in Fig. 2 and they open sidewise instead of vertically. Steel liners *A* and *B*, attached to separate die-blocks *C* and *D*, respectively, form the die-cavity. These liners are made of 3/16 inch thick cold rolled steel. Blocks *C* and *D* are ordinary iron castings. Pockets in the die-blocks, as shown at *X* and *Y*, permit the circulation of cool or preheated air around the steel liners for obtaining chilled or non-chilled castings, as desired.

The steel liners expand and contract freely in the die-casting operations. In cooling, the castings always shrink from the liners and thus fall from the dies without the aid of ejector devices. Cores made of cold rolled sheet steel and split crosswise at one point around their periphery so that they can shrink in diameter as the die-casting cools, are generally used to form holes in the center of parts. Such a core is seen at *A* in Fig. 6. It is used to form the hole in the pipe flange at *B*. At *C* is seen one of the die-blocks in which the pipe flange is cast, but the steel liner is not illustrated. At *D* are the two halves of the die gate.

Core *A* is expanded to its maximum diameter for each die-casting operation by the application of pressure along its upper edge as the two dies are closed together. When the part shrinks in cooling, the split edges of the core slide along each other, with the result that the diameter of the core is reduced. Dowel-pins insure correct registry of dies each time that they are closed.

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